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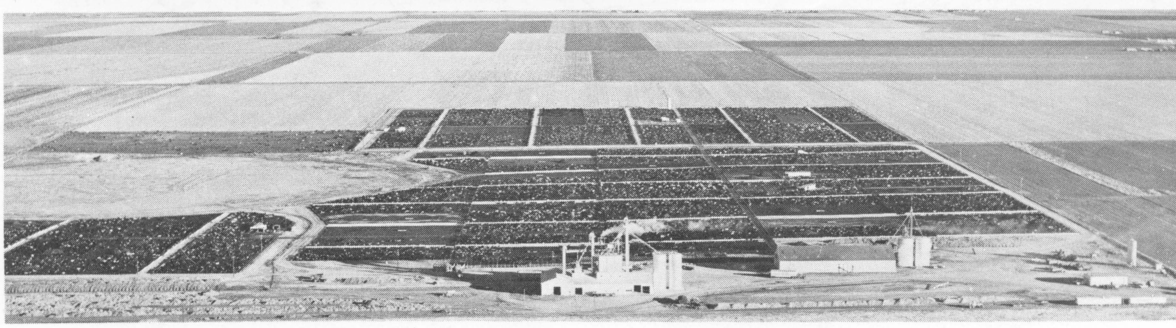

# Sherm Soils

## Distribution, Importance, Variability & Management

The Texas Agricultural Experiment Station, Neville P. Clarke, Director, College Station, Texas
in cooperation with
United States Department of Agriculture, Agricultural Research Service and Soil Conservation Service

## Contents



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*Cover photos—Some of the uses of Sherm soils are irrigated and dryland grain crops and cattle finishing. (USDA-Soil Conservation Service photo).*

# SHERM SOILS—DISTRIBUTION, IMPORTANCE, VARIABILITY, AND MANAGEMENT[1]

Paul W. Unger and Fred B. Pringle

## INTRODUCTION

### Area Occupied by Sherm Soils

Sherm soils[2] occupy parts of eight counties in the northern High Plains of Texas and parts of two counties in the Oklahoma Panhandle (Figures 1, 2). The portions of different counties occupied by Sherm soil range from about 0.4 to 51 percent (Table 2).

The area of Sherm soils ranges from about 101° 30′ to 103° 30′ west longitude and from about 35° 40′ to 36° 40′ north latitude. This area is bounded by the breaks above the North Canadian River on the north, the caprock escarpment at the Canadian River on the south, the caprock escarpment at the High Plains-Rolling Plains boundary on the east, and a catena of loamy soils extending from Kerrick to Channing on the west. Within the area of occurrence, Sherm soils occupy about 75 percent of the land surface. Elevation ranges from about 2,800 to 4,200 ft above mean sea level. The area is in a subhumid to semiarid climatic zone where average annual precipitation ranges from about 16 inches at the western edge to about 22 inches at the eastern edge (Table 3). Also listed in Table 3 are the average length and dates of the frost-free period, average daily maximum and minimum temperatures, and average annual precipitation in counties where Sherm soils occur.

Sherm soils occupy about 1.3 million acres in Texas (Table 2) and are among the most extensive arable soils in the state. Sherm soils also occupy a small area of Oklahoma. Other major arable soils in Texas are Pullman with 3.8 million acres and Amarillo with 2.5 million acres in the southern High Plains, and Houston Black with 1.5 million acres in the Blacklands area.

Soil taxonomy was implemented for use in the National Cooperative Soil Survey in the mid-1960's. A few of the published soil surveys on the Texas High Plains were completed before the advent of this system. But most were conducted while the soil classification system was in its infancy. Since then, soil taxonomy has undergone many refinements. Because of this and the accumulation

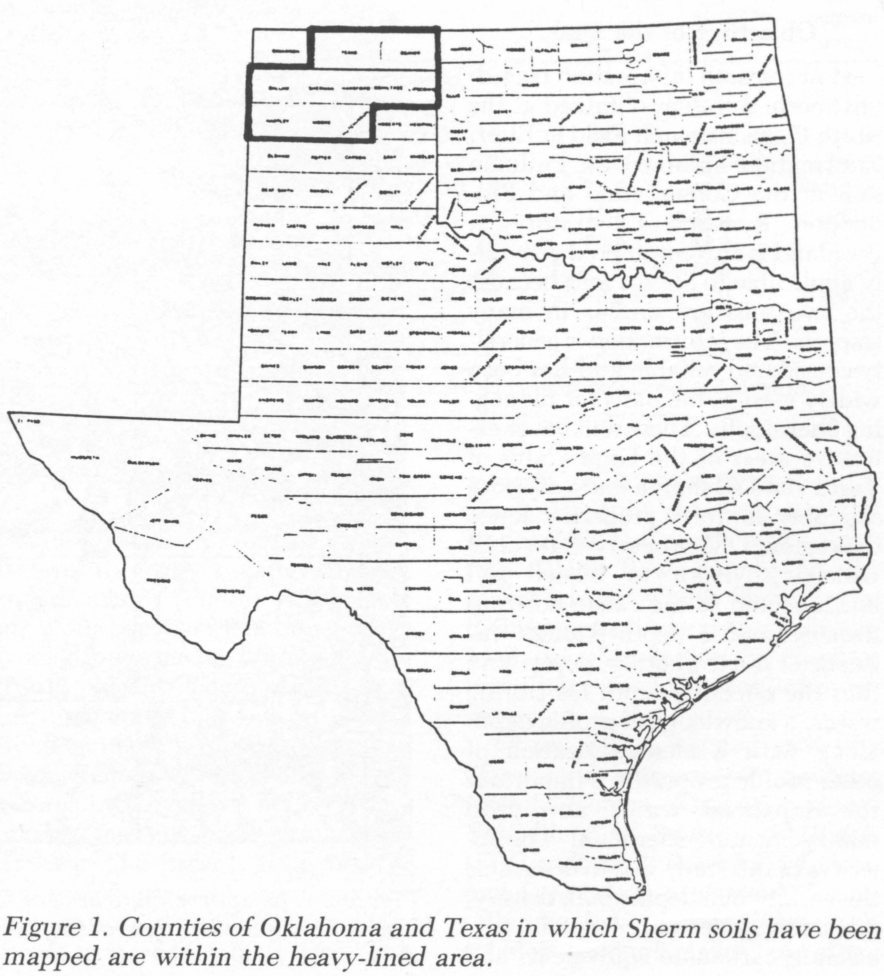

*Figure 1. Counties of Oklahoma and Texas in which Sherm soils have been mapped are within the heavy-lined area.*

[1]Contribution from USDA, Agricultural Research Service, P.O. Drawer 10, Bushland, Texas 79012, and USDA, Soil Conservation Service, Amarillo, Texas 79101.

[2]See Table 1 for classification of soils mentioned in this report.

TABLE 1. CLASSIFICATION OF SOILS MENTIONED IN THE TEXT AND FIGURES

| Series | Classification |
|---|---|
| Amarillo | Fine-loamy, mixed, thermic Aridic Paleustalfs |
| Berthoud | Fine-loamy, mixed, mesic Aridic Ustochrepts |
| Conlen | Fine-loamy, carbonatic, mesic Calciorthidic Paleustolls |
| Dumas | Fine-loamy, mixed, mesic Aridic Paleustolls |
| Gruver | Fine, mixed, mesic Aridic Paleustolls |
| Houston Black | Fine, montmorillonitic, thermic Udic Pellustersts |
| Humbarger | Fine-loamy, mixed, mesic Cumulic Haplustolls |
| Likes | Mixed, thermic Typic Ustipsamments |
| Ness | Fine, montmorillonitic, mesic Udic Pellusterts |
| Plack | Loamy, mixed, mesic, shallow Petroclacic Calciustolls |
| Pullman | Fine, mixed, thermic Torrertic Paleustolls |
| Richfield | Fine, montmorillonitic, mesic Aridic Argiustolls |
| Sherm | Fine, mixed, mesic Torrertic Paleustolls |
| Sunray | Fine-loamy, mixed, mesic Calciorthidic Paleustolls |
| Ulysses | Fine-silty, mixed, mesic Aridic Haplustolls |

of additional laboratory and field data, the central concept of some soil series has changed. Accordingly, all soils included in the Sherm series do not conform to the current classification criteria. However, each sample site in this report is representative of the Sherm soil in its geographic locale. These soils met the criteria in force at the time individual county soil surveys were in progress.

### Objectives of the Study

Most research information regarding Sherm soils was obtained at the North Plains Research Field at Etter. Information obtained on Pullman soils at the Conservation and Production Research Laboratory at Bushland is also considered generally applicable to Sherm soils because the two soils are similar in many respects. The information is generally considered reliable and has been widely used as the basis for managing Sherm soils. These soils cover extensive areas of the High Plains of Texas and Oklahoma and vary considerably in profile properties across the region. One property that varies widely is depth to buried soil horizons and to the calcic horizon. Because profile depth strongly influences plant rooting depth and thus the effective depth for storing water, a knowledge of profile depth along with a characterization of other profile properties is important for improved water and crop management on Sherm soil. The objective of this study was to determine the variation in depth, bulk density, texture, organic matter content, pH, calcium carbonate equivalent, and water retention of the different horizons of Sherm soil as affected by location in the region. Water infiltration at the different locations was also determined.

### History of the Sherm Series

The Sherm series is classified by soil taxonomists as a member of the fine, mixed, mesic family of Torrertic Paleustolls. The soil was formed from fine-textured sediments of the High Plains eolian (wind-deposited) mantle under a dense cover of short grasses (Figure 3).

The Sherm series was established in 1970 during the soil survey of Sherman County, Texas (SCS, 1975b). It was named after Sherman County in the northern Texas Panhandle. Before 1970, Sherm soils were included in other series, mainly the Pullman and Richfield series. The process of inventorying and classifying soils on the High Plains began with the publication of the Reconnaissance Soil Survey of the Panhandle Region of Texas in 1910. In this survey, Sherm soils were called Amarillo silty clay loam. The Amarillo series was established in this survey and included soils ranging from sands to clays.

As soil surveys and investigations continued, differences in the physical and chemical properties of

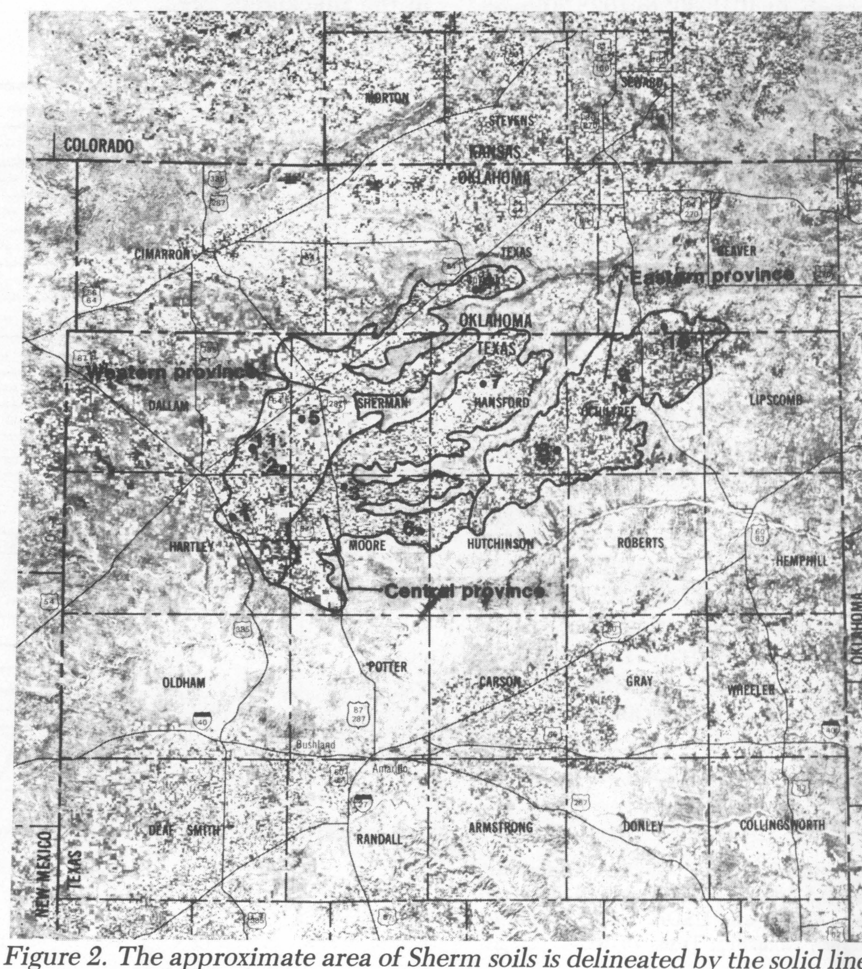


*Figure 2. The approximate area of Sherm soils is delineated by the solid line. The approximate locations of the sampling sites are indicated by the numbered dots.*

TABLE 2. AREAS OCCUPIED BY SHERM SOILS

| County, state | Slope | Mapping unit area | Portion of county | Total series area[1] | Total cropland | Irrigated cropland | Rangeland | Other land[2] |
|---|---|---|---|---|---|---|---|---|
| | % | acres | % | | | acres | | |
| Beaver, Oklahoma | 0-1 | 6,913 | 0.6 | 6,910 | 6,365 | 2,169 | 200 | 345 |
| Dallam, Texas | 0-1 | 32,800 | 3.5 | 32,800 | 23,944 | 13,887 | 7,216 | 1,640 |
| Hansford, Texas | 0-1 | 277,118 | 47.7 | 293,900 | 274,427 | 210,436 | 15,582 | 3,981 |
| | 0-1 | 16,553 | 2.8 | | | | | |
| | 0-1, erod. | 322 | <0.1 | | | | | |
| Hartley, Texas | 0-1 | 71,100 | 7.5 | 71,100 | 58,620 | 50,609 | 9,028 | 3,452 |
| Hutchinson, Texas | 0-1 | 101,690 | 17.4 | 106,010 | 96,777 | 76,071 | 7,185 | 2,048 |
| | 1-3 | 4,320 | 0.7 | | | | | |
| Lipscomb, Texas | 0-1 | 7,850 | 1.3 | 9,320 | 8,620 | 3,730 | 325 | 375 |
| | 1-3 | 1,470 | 0.3 | | | | | |
| Moore, Texas | 0-1 | 266,578 | 45.6 | 276,540 | 223,208 | 189,828 | 42,527 | 10,805 |
| | 1-3 | 9,960 | 1.7 | | | | | |
| Ochiltree, Texas | 0-1 | 283,431 | 48.8 | 291,790 | 275,501 | 109,110 | 12,892 | 3,397 |
| | 1-3 | 8,357 | 1.4 | | | | | |
| Sherman, Texas | 0-1 | 182,565 | 31.0 | 182,570 | 161,428 | 135,104 | 16,531 | 4,611 |
| Texas, Oklahoma | 0-1 | 4,166 | 0.4 | 4,170 | 4,145 | 1,488 | — | 25 |
| Total | | | | 1,275,200 | 1,133,035 | 792,432 | 111,486 | 30,679 |

[1]Includes total area for all slopes and conditions. Totals for the different slopes and conditions may not equal the total for series because of rounding values to the nearest 10 acres.
[2]Includes land in roads, towns, and other non-agricultural uses.

TABLE 3. ELEVATION AND CLIMATIC FACTORS IN COUNTIES HAVING SHERM SOILS

| County, state, station | Elev | Avg annual lake evaporation | Avg growing season | | Avg daily temp Max | Avg daily temp Min | Avg annual precip[1] |
|---|---|---|---|---|---|---|---|
| | ft | in | d | period | °F | | in |
| Beaver, Oklahoma, Beaver | 2,560[2] | 62 | 198 | Apr 5-Oct 20 | 72.4 | 39.6 | 17.00 |
| Dallam, Texas, Dalhart | 3,989 | 60 | 178 | Apr 23-Oct 18 | 70.7 | 40.5 | 16.25 |
| Hansford, Texas, Spearman | 3,250 | 63 | 184 | Apr 20-Oct 22 | 71.3 | 40.8 | 21.26 |
| Hartley, Texas, Dalhart | 3,989 | 60 | 178 | Apr 23-Oct 18 | 70.7 | 40.5 | 16.25 |
| Hutchinson, Texas, Borger | 3,140[2] | 65 | 187 | Apr 20-Oct 24 | 73.4 | 45.5 | 20.70 |
| Lipscomb, Texas, Follett | 2,780[2] | 66 | 202 | Apr 10-Oct 29 | 70.4 | 43.3 | 21.57 |
| Moore, Texas, Dumas | 3,500 | 64 | 185 | Apr 20-Oct 22 | 71.0 | 41.8 | 18.95 |
| Ochiltree, Texas, Perryton | 2,930 | 64 | 191 | Apr 18-Oct 26 | 72.0 | 42.0 | 21.13 |
| Sherman, Texas, Stratford | 3,699 | 62 | 182 | Apr 23-Oct 22 | 70.9 | 39.9 | 16.55 |
| Texas, Oklahoma, Goodwell | 3,300 | 64 | 191 | Apr 17-Oct 25 | 70.5 | 39.8 | 17.00 |

[1]Average values for monthly maximum and minimum temperatures and precipitation are available in most published soil surveys.
[2]Recording station not located in Sherm series area of occurrence.

soils were noted. This led to the recognition of other soil series. Further investigations led to the establishment of the Pullman series, which was first recognized in the Soil Survey of Potter County published in 1929. Sherm soils were included in the Pullman series at that time.

In 1970, the Sherm series was established for those soils north of the Canadian River that had previously been classified as Pullman. The Sherm series has a mean annual soil temperature of less than 59°F at a 20-inch depth. For Pullman soils, the mean temperature is greater than 59°F.

## Physiography

The topography consists of nearly level to gently sloping, smooth, treeless plains (Figure 4). Surfaces are plane to convex and slopes range from 0 to 3 percent, but are mainly 0 to 2 percent. These broad plains are interrupted by a few creeks and by the numerous playas, or shallow lakes, containing other soils. Except where pitted by playas or disected by creeks, the surface is remarkably smooth. The playas range from a few square yards to several square miles in surface area, and from a few inches to more than 50 ft deep. The average grade of the High Plains is about 10 ft/mi to the southwest. Runoff follows a poorly defined pattern. Water flows mainly into the playas, from which there is no definite outlet. The water collected in playas is lost mainly by evaporation, but some of it is used for irrigation.

Other soils associated with the Sherm series in its area of occurrence include Conlen, Dumas, Gruver, Ness, Richfield, Sunray, and Ulysses (Figures 5, 6, 7, 8, and 9). Conlen and Sunray are calcareous, loamy soils on low convex ridges, on sideslopes around playas, and along

*Figure 3. Dense cover of short grasses on Sherm soil.*

*Figure 4. Sprinkler-irrigated fields in an area showing the typical topography of the Sherm soil region (USDA-Soil Conservation Service photo).*

draws. Dumas and Gruver soils are on smooth plains and are similar in appearance to Sherm. But the Bt horizons of these soils are somewhat redder, have loamy textures, and are more permeable. Ness soils are dark gray and have clay textures throughout. They are on playa bottoms. Richfield soils are on nearly level to gently sloping smooth plains along the margins of the area. They are similar in appearance to the Sherm series, but the Bt horizon has a loamy texture and is more permeable. Ulysses soils are calcareous, have silty clay loam textures, and are more permeable than Sherm soils. They are on convex knolls or oval-shaped hills that rise above the broad smooth plains.

There are differences in the morphological properties of the Sherm series that are related to geographic location. There differences affect soil water storage capacity, which in turn affects water management on these soils. The varying morphological features are depth to a strong calcic horizon (>30 percent calcium carbonate—$CaCO_3$), depth to a layer of strongly contrasting material, soil texture, and permeability.

An analysis of soil survey field notes for seven counties and additional profile observations revealed that depth to a strong calcic horizon ranges from 40 inches to more than 93 inches. Observations by soil and plant scientists indicate that calcic horizons containing more than 30 percent lime inhibit root development in most crops. Based on laboratory determinations using a simple volume calcimeter, the average $CaCO_3$ content in the Btk horizon of Sherm soils is about 50 percent.

To present a clearer understanding of these soils as they relate to geographic location, it is convenient to divide the large area into three soil provinces (Figure 2). The western province includes the eastern portions of Dallam and Hartley Counties and the northwestern corner of Moore County. Also included is that portion of Sherman County northwest of Coldwater Creek and the area occupied by Sherm soils in Texas County, Oklahoma. Slopes are nearly level to gently undulating (Figure 6). Surfaces are smooth and slightly convex. In the western province, Sherm soils are intermingled with areas of Conlen, Dumas, Gruver, Ness, and Sunray soils. Sherm soils make up about 40 percent of the total area, Gruver soils make up 26 percent, and Dumas soils 14 percent. Conlen, Ness, and Sunray soils make up the remaining 20 percent. Conlen and Sunray soils are on low convex ridges and sideslopes around playas. Ness soils are on playa bottoms. Dumas and Gruver soils occupy the same general landscape as Sherm, although their surfaces are more convex. Buried profiles with contrasting textures are common below depths of 24 to 40 inches. Because of these discontinuities, the depth to a strong calcic horizon is quite variable. It ranges from less than 40 inches to more than 72 inches deep. In addition, the $CaCO_3$ content is erratic, ranging from about 20 to 50 percent.

The central province extends from near the Texas-Oklahoma state line southwest to the caprock escarpment at the Canadian River, and is bounded on the east roughly by Palo Duro Creek and South Palo Duro Creek. It includes parts of Hansford, Hutchinson, Moore, and Sherman Counties. Slopes are nearly level to gently sloping, and surfaces are plane to slightly convex (Figure 7). Sherm soils comprise about 85 percent of the total area. The remainder is mainly Dumas, Gruver, Ness, and Sunray soils. Dumas and Gruver soils are on smooth plains with slightly convex surfaces. Ness soils are on playa bottoms, and Sunray soils are on sideslopes around playas and along draws. Readily discernable buried soil profiles are noticeably absent in this province, and consequently, the soil above a strong calcic horizon is more uniform in depth. The depth to a strong calcic horizon ranges from 48 to 60 inches, but is commonly about 55 inches. Calcium carbonate content ranges from about 40 percent to more than 60 percent and averages about 53 percent.

The eastern province covers an area east of Palo Duro Creek and north of the caprock escarpment at the Canadian River. It is bounded on the north by the breaks into the North Canadian River and on the east by the caprock escarpment that separates the High Plains from the Rolling Plains. Included are parts of Hansford, Hutchinson, Lipscomb,

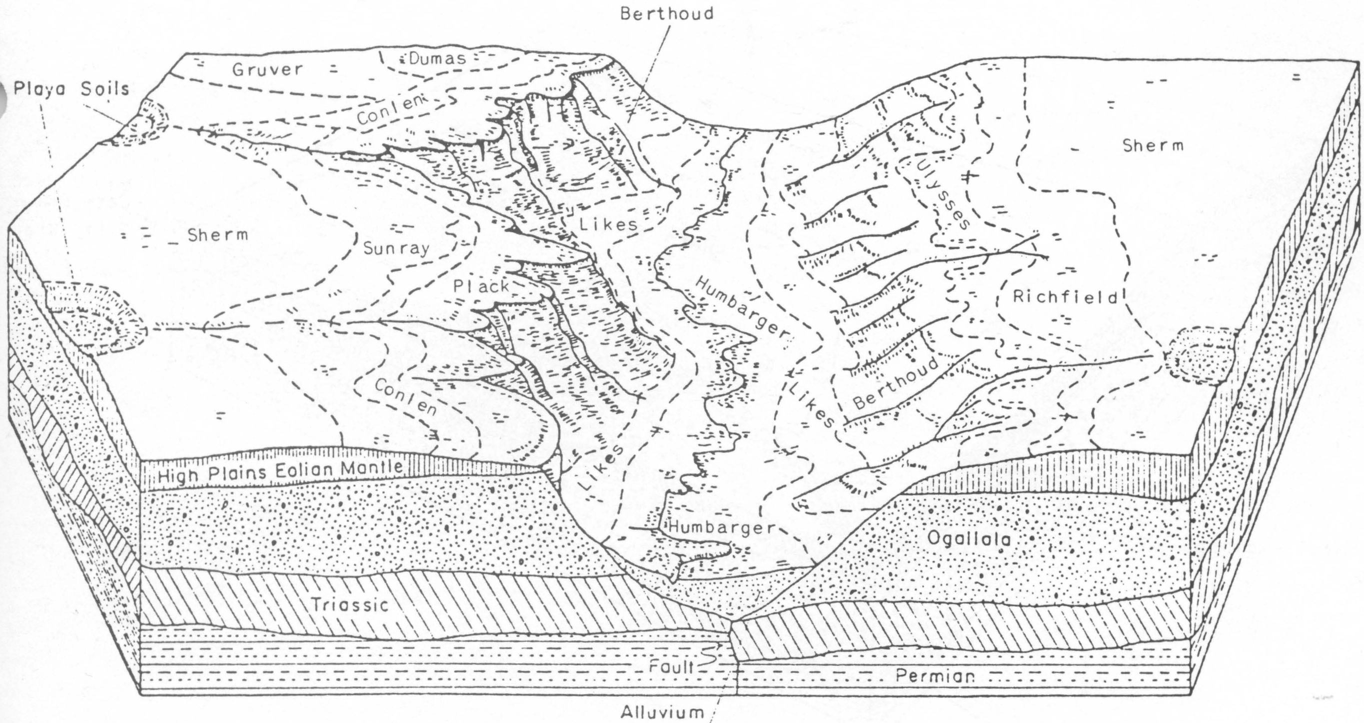


*Figure 5. Major soils and underlying formations in the area occupied by Sherm soils.*

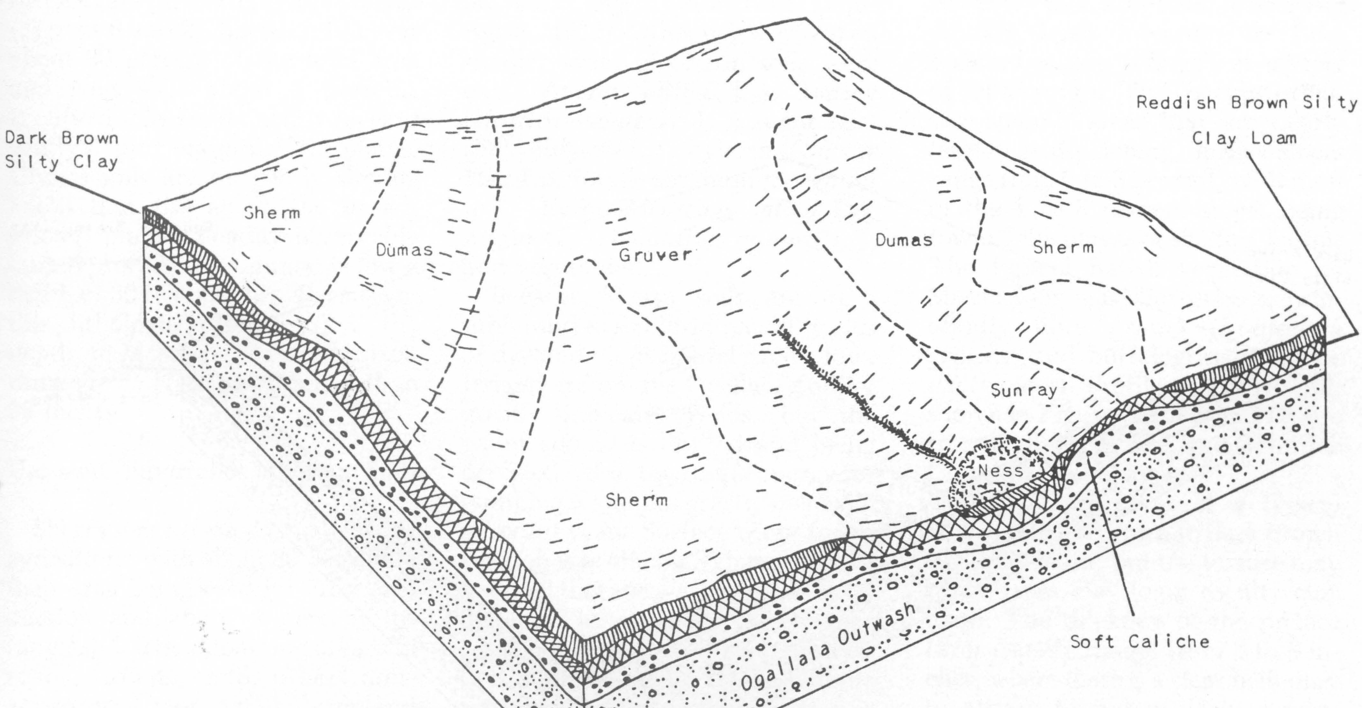


*Figure 6. Soil pattern in the western province.*

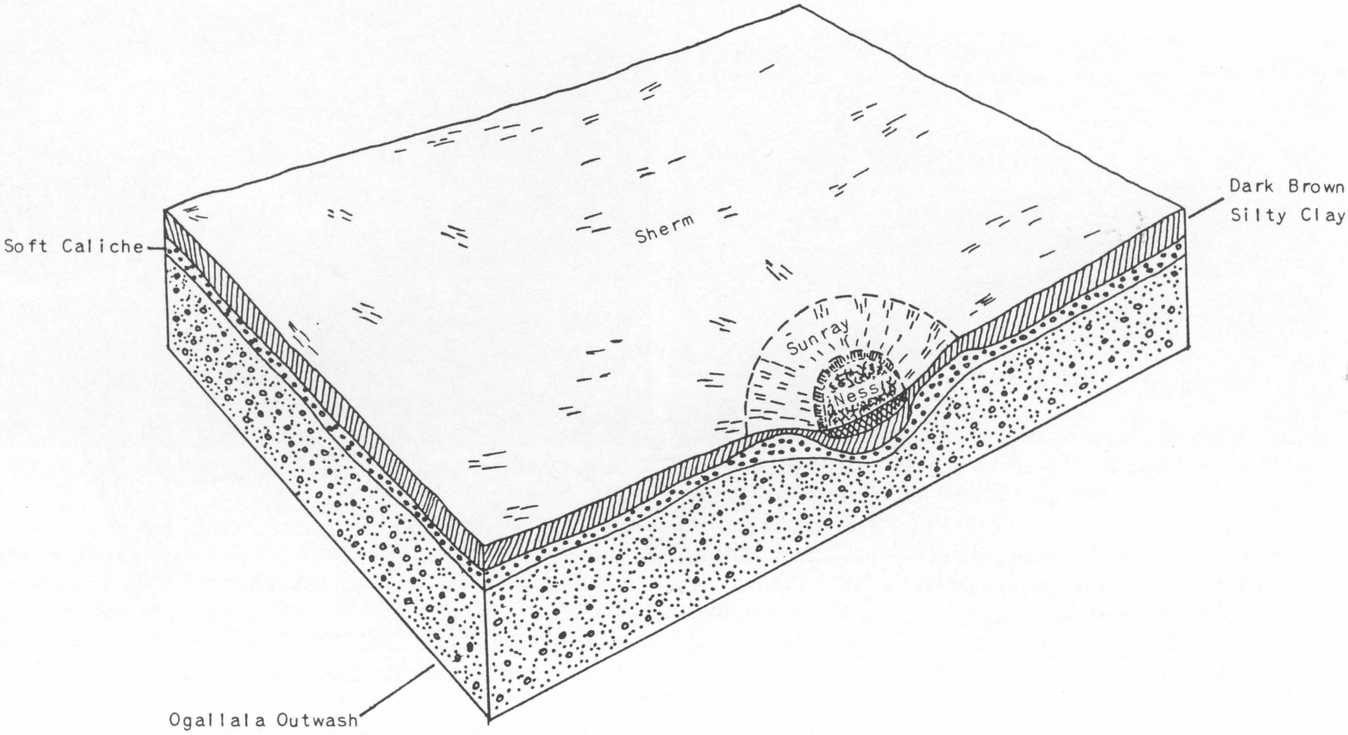


*Figure 7. Soil pattern in the central province.*

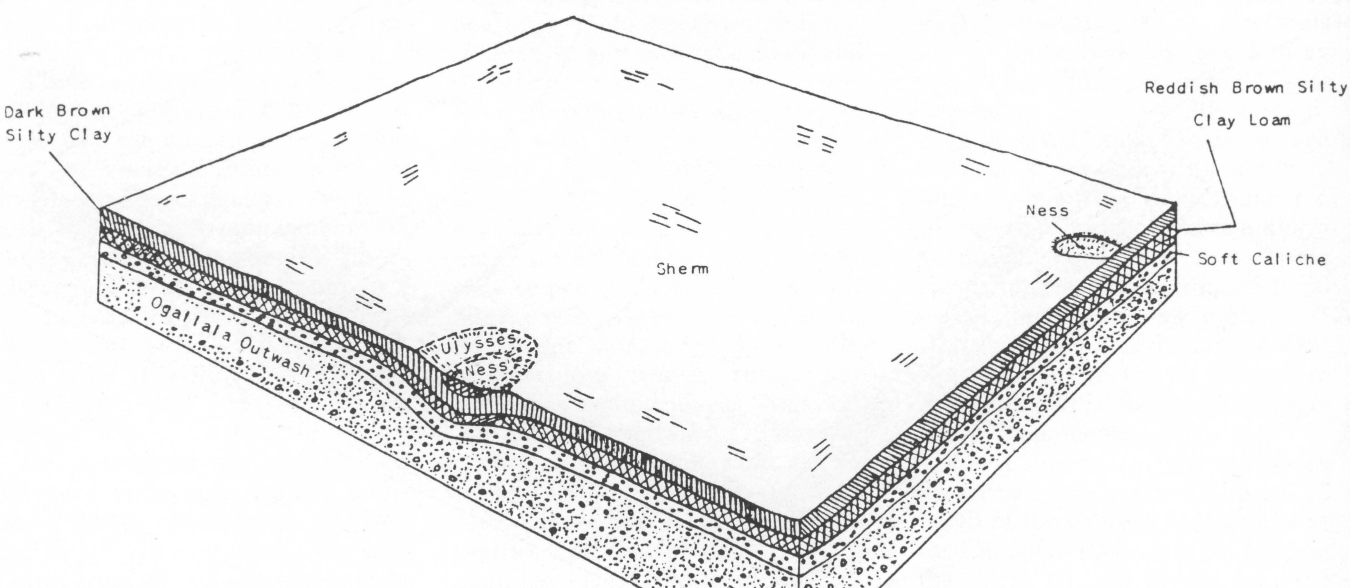


*Figure 8. Soil pattern in the southern part of the eastern province.*

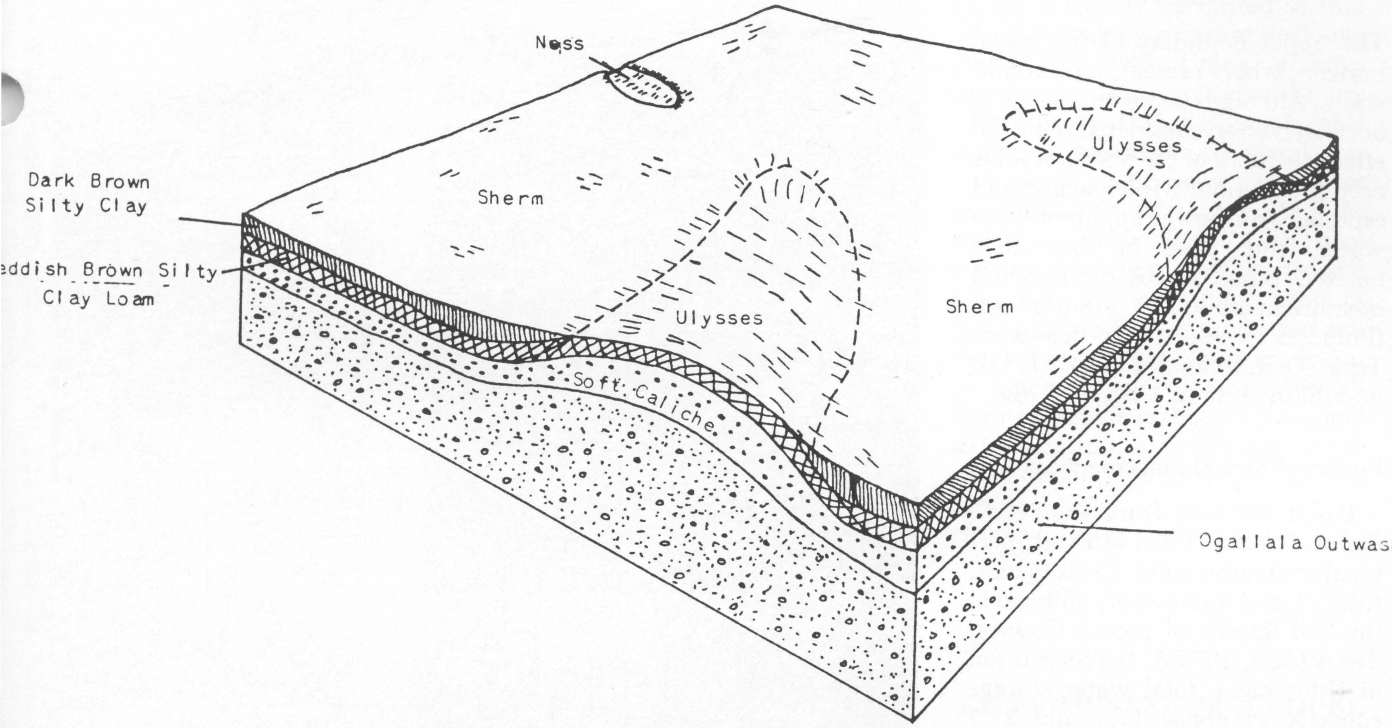


*Figure 9. Soil pattern in the northern part of the eastern province.*

and Ochiltree Counties in Texas and Beaver County in Oklahoma. Slopes are nearly level to gently sloping and surfaces are plane to slightly convex (Figures 8 and 9). Sherm soils cover about 90 percent of the total area and Ness soils about 5 percent. Richfield soils are on nearly level to gently sloping margins of the plains. Ulysses soils are on gently sloping knolls that rise above the broad, smooth plains. Readily observable buried profiles are common below a depth of 30 to 40 inches. Because of this lithologic discontinuity, the depth to a strong calcic horizon ranges from 65 inches to more than 93 inches.

### Uses and Importance of Sherm Soils

Sherm soils are used primarily for agriculture, with about 89 percent of their area being used for crop production and about 9 percent for rangeland. The remaining area is in roads, towns, and other nonagricultural uses. Of the cropland area of Sherm soil, about 70 percent is irrigated and 30 percent is dryland (Table 2). The area of irrigated Sherm soil represents about 10 percent of all irrigated land in Texas. Wheat (*Triticum aestivum* L.), grain sorghum [*Sorghum bicolor* L. (Moench)], and corn (*Zea mays* L.) were the major field crops produced on Sherm soils in 1982 (Texas Dept. Agric., 1982). Other crops grown on smaller areas of Sherm soils were oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.), sugar beet (*Beta vulgaris* L.), soybean (*Glycine max* L.), forage sorghum (*Sorghum* sp.), alfalfa (*Medicago sativa* L.), sunflower (*Helianthus annuus* L.), and vegetables.

Because Sherm soils are in a subhumid to semiarid region, yields of dryland crops are relatively low. Irrigation from the Ogallala Aquifer greatly increases yields, but the water supply is limited and being depleted. Also, the cost of energy for pumping water has greatly increased in recent years. Surface water for irrigation is negligible. Therefore, it is essential that the water be used as efficiently as possible to enhance economic returns from crop production and to delay the inevitable return to dryland crop production as long as possible. When dryland farming replaces irrigated farming, even if only on the Sherm soils, a significant amount of the total production of some crops in Texas will be lost.

### Typical Site for Sherm Soils

Sherm soils developed in a relatively cool, subhumid to semiarid climate from medium- to fine-textured sediments largely or entirely of eolian origin. They occupy extensive smooth areas that are nearly level to gently sloping. Surface slopes range from 0 to 3 percent, with most of the 1 to 3 percent slopes being toward the playas or shallow basins. The typical native vegetation on Sherm soils was shortgrasses, principally blue grama (*Bouteloua gracilis*) and buffalograss (*Buchloe dactyloides*). Profiles of Sherm soil, shown in Figures 10, 11, and 12, are from Dallam, Moore, and Ochiltree Counties, respectively.

The surface layer of a typical Sherm soil is a brown to dark brown silty clay loam, but the texture may range from clay loam to silty clay loam. The thickness of the surface layer usually ranges from 6 to 8 inches, where there is a clear boundary to a dark brown to dark grayish-brown clay or silty clay with blocky structure (Figures 10, 11, and 12). The soil may contain buried horizons of older soils at 3 to 5 ft below the surface. Theu buried horizons usually have a clay loam texture.

The upper boundary of the calcic horizon, where present, is clear and wavy. Although depth to the calcic horizon is often considered to be the effective depth of the Sherm soil for crop production, winter wheat and especially sunflower apparently use water from deep in the calcic horizon, based on observations and measurements on a similar soil (Pullman clay loam) at Bushland, Texas (O.R. Jones, Bushland, Texas, unpublished data; Unger, 1978a).

### Present Water Management Systems

Based on data from the North Plains Research Field at Etter (personal communication, Cecil Regier, Etter, Texas) and values published in the Soil Survey of Moore County, Texas (SCS, 1975a), the Sherm soil at Etter has a total water storage capacity of about 17.1 and 24.7 inches to 4- and 6-foot profile depths, respectively. Of the total water storage capacity, about 8.7 and 12.3 inches are available for use by plants. The remainder (8.4 and 12.4 inches to 4- and 6-foot depths,
12.4 inches to 4- and 6-foot depths,
respectively) is held at tensions (energy levels) against which plants cannot extract the water.

Because of limited and erratic precipitation during the growing season, it is desirable to have the soil profile filled to capacity with water at planting time, especially for dryland crops. When the soil is filled to capacity at planting, crops usually experience less water stress during the growing season than when the soil contains a limited amount of water. Crop yields usually are higher when water stress is not severe during the growing season.

Although irrigation can provide water to crops, soil water content at planting is still important because any water stored from precipitation reduces the amount required from irrigation. When water storage from precipitation is low, a preplant or emergence irrigation is often used to increase the soil water content. Because the Sherm soil is slowly permeable, relatively long periods of water application are required to add large amounts of water to the soil. With furrow irrigation (Figure 13), which is the most common method, considerable tailwater

*Figure 10. Sherm soil profile in Dallam County, Texas. Major units are in feet (USDA-Soil Conservation Service photo).*

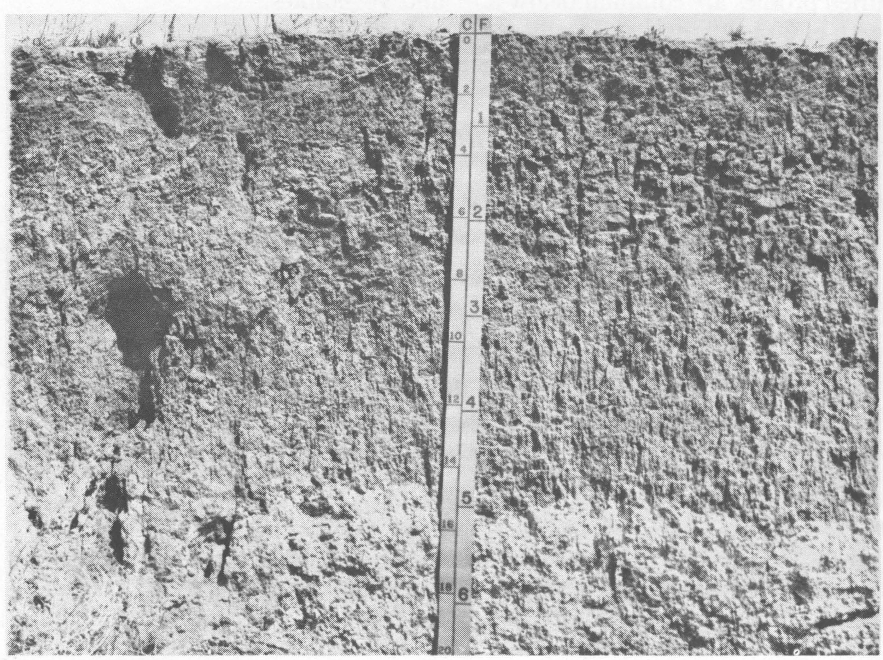

*Figure 11. Sherm soil profile in Moore County, Texas. Units are in cm ($x10^{-1}$) and feet.*

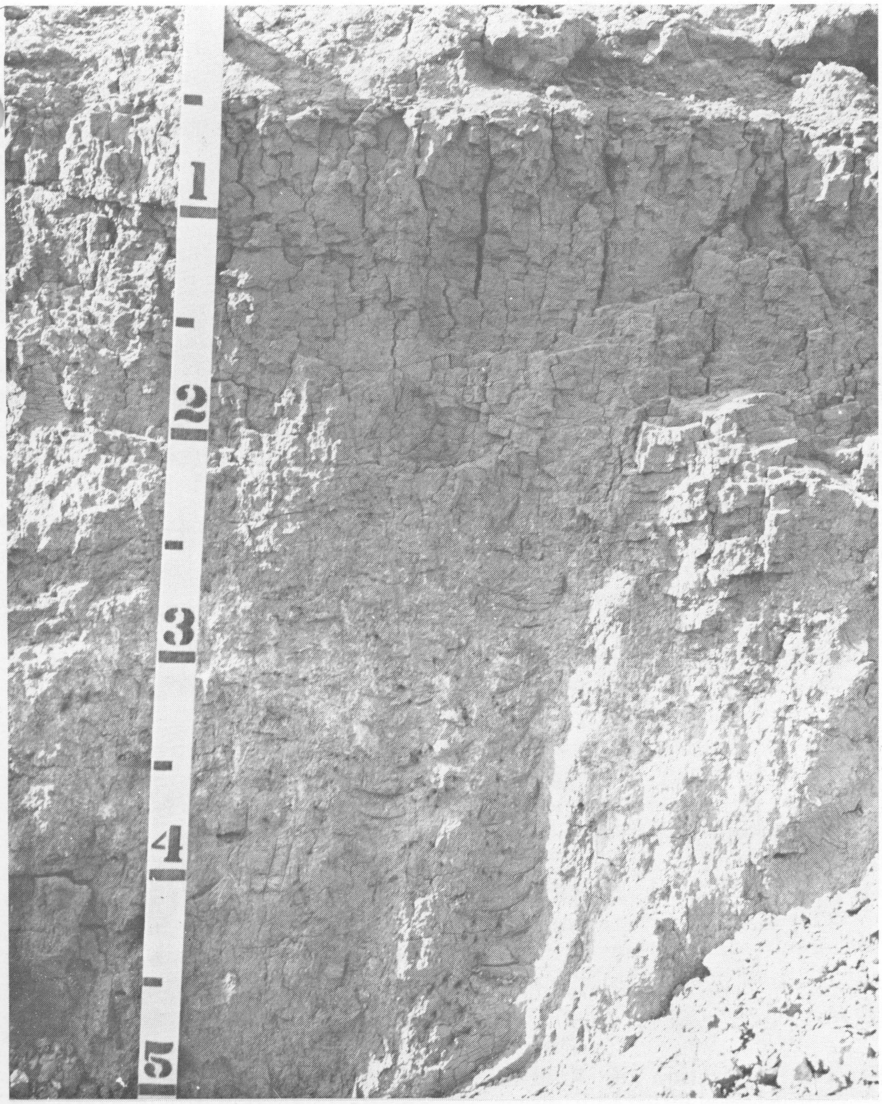


*Figure 12. Sherm soil profile in Ochiltree County, Texas. Units are in feet (USDA-Soil Conservation Service photo).*

*Figure 13. Furrow irrigation through gated pipe.*

runoff is usually permitted so that adequate water is stored at the lower end of the field. Unless effective tailwater recovery systems (Figure 14) are used, tailwater runoff reduces the efficiency of water use.

In recent years, many center-pivot sprinkler systems (Figure 15) have been installed on Sherm soil. These systems, when properly designed and operated, reduce runoff amount compared to furrow irrigation but require considerably more energy input than furrow irrigation. With all farming systems on both dryland and irrigated land, a knowledge of the water-holding capacity of the soil profile (Figure 16) is important for effective water management.

## EXPERIMENTAL PROCEDURE

### Site Selection

To obtain samples that would represent a near-complete range in the expected variation in soil properties, sites were selected at 11 widely separated locations across the region. The sampling sites were in Dallam, Hansford, Hartley, Moore, Ochiltree, and Sherman Counties in the Texas Panhandle, and in Beaver and Texas Counties in the Oklahoma Panhandle. Although the locations were widely separated, samples were not obtained near the edges of the region to avoid zones of transition to other soils. Likewise, locations of transition to other soils within the region were avoided. The sampling was restricted to "typical" Sherm soil sites for the particular location.

### Sampling Sites

The 11 sampling sites are indicated on Figure 2. Brief descriptions of the locations are given with the profile descriptions in the Results and Discussion section. All sites were in irrigated fields on nearly level uplands of the High Plains. Sites 1, 2, 4, 5, and 11 were in the western province; Sites 3, 6, 7 in the central province; and Sites 8, 9, and 10 in the eastern province.

*Figure 14. Tailwater recovery system showing recovery pit and lake pump to recycle water to cropland. (USDA-Soil Conservation Service photo).*

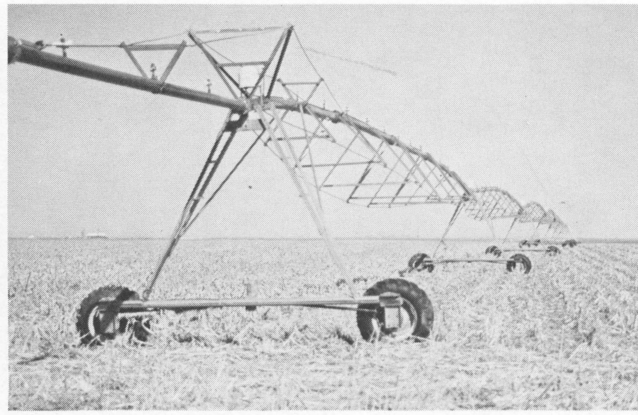

*Figure 15. Sprinkler-irrigation system near Dalhart, Texas.*

**Sampling Techniques**

At each sampling site, loose soil of the plow layer, usually to the depth of the Ap horizon, was removed before obtaining core samples with a hydrualically-operated, pickup-mounted core sampler. The inside diameter of the cutting tip was 1.625 inches. The first two cores at each site were used for profile description. Other cores were then taken and separated into depth segments based on the thickness of the different horizons. Three or more cores were obtained to provide adequate material from each depth for determining water retention. The core segments were immediately dipped in a liquified saran solution, which made the cores rigid after drying. After the saran had dried, the individual segments were wrapped in plastic bags for transport to the laboratory. Two additional cores were obtained and sectioned by horizons to obtain samples for bulk density determination. Two samples of the surface layer of soil were also collected in bags at each site. At a different time, three water infiltration determinations were made at each site with recorder-equipped, constant head, double-ring infiltrometers. These double-rings are seated into the most restrictive subsurface layer, and 1.5-inch head of water is maintained for the duration of the test. Water surfaces are covered to prevent evaporation. Placement of individual infiltrometers is determined after examining the field to reflect tillage zone conditions at the time of testing.

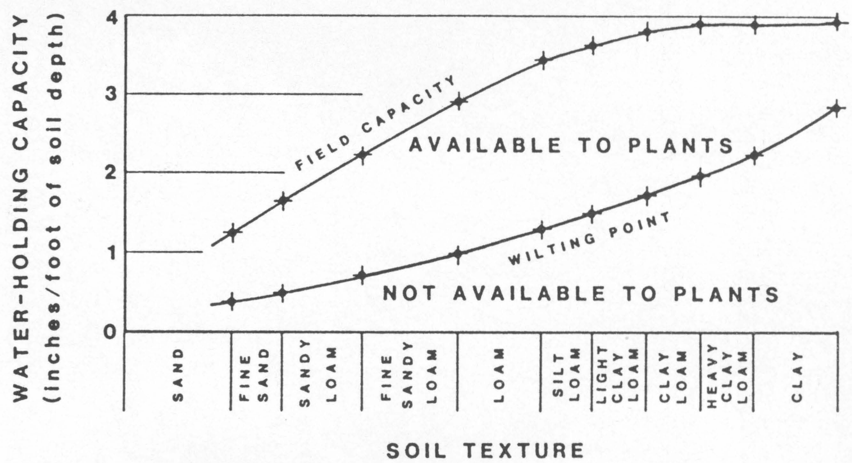


*Figure 16. Typical water-holding capacities of soils with different textures (adapted from USDA, 1955).*

**Sample Preparation and Analyses**

The core samples used for water retention measurements were cut into sections about 0.75 inch long and reinforced with cellophane tape before making the measurements at -⅓ and -15 bars matric potential. The measurements were made with pressure plate equipment using four sections from each depth at each potential.

Bulk density was determined by drying the cores at 105°C, then weighing them. Soil from these cores was retained and ground to pass a 2-mm sieve. Subsamples of this sieved soil were then used to determine organic matter content by the Walkley-Black method (Jackson, 1958), pH (1:1 soil:water ratio), and particle size distribution (mechanical analyses) by the hydrometer method (Day, 1965). The sand from the particle size distribution analyses was subsequently sieved to determine the size distribution of the sand in the samples.

Samples of surface soil were air-dried, ground, and passed through a 2-mm sieve. Subsamples of surface soil were used to determine water retention, particle size distribution, organic matter content, and pH by the methods described above.

The relationships among various Ap, Btl, and Bt2 horizons, total profile characteristics, total water infiltration in 10 min and 20 hr, and infiltration rates at these times were investigated by multiple linear regression analyses. The horizon and profile characteristics investigated were thickness; sand, silt, clay, and organic matter content; and bulk density. For the Ap, Btl, and Bt2 horizons, actual values were used. For the entire profile, weighted mean values were calculated from values for the different horizons, resulting in one value for each variable of the profile at each site.

Besides the partial regression coefficients and the coefficient of correlation (R), standardized partial regression coefficients and *t*-values were also calculated (Ezekiel and Fox, 1959; Steel and Torrie, 1960). Based on the standardized coefficients, the independent variables were ranked numerically in order of their relative importance for influencing total infiltration or infiltration rates. All independent variables were used in the initial analysis for each set of data. In subsequent analyses, the lowest-ranking variable was excluded, which resulted in the last analysis being a simple linear regression analysis.

## RESULTS AND DISCUSSION

### Profile Descriptions

This section describes the profiles at the 11 sites and their locations. The profile descriptions are based on examination and determinations made in the field immediately after extracting the cores. Although data in subsequent sections are based mainly on horizons above the calcic horizon, the calcic horizon is included in the profile descriptions. The descriptions are:

*Site No. 1*

Soil Type: Sherm clay loam

Location: Hartley County, Texas; in a cultivated field 1,300 ft east of unpaved county road, 1.7 mi northwest and 0.25 mi west of the intersection of U.S. Highway 385 and Farm Road 998 in Hartley.

Pedon Description:

Sample No. S81TX205-1-(1-6)

Ap—0 to 6 inches; brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; weak, medium granular and subangular blocky structure; slightly hard, friable; many fine and medium roots; few fine pores; mildly alkaline; abrupt smooth boundary.

Btl—6 to 18 inches; brown (7.5YR 4/2) clay, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; few small stress surfaces in lower part; extremely hard, extremely firm; common fine roots; few very fine pores; thin continuous clay films; few vertical cracks; mildly alkaline; gradual smooth boundary.

Bt2—18 to 28 inches; brown (7.5YR 5/2) clay loam, brown (7.5YR 4/2) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few very fine pores; thin continuous clay films; few small vertical cracks; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt3—28 to 36 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium blocky; very hard, very firm; few fine roots; common fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt4—36 to 60 inches; yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; weak coarse prismatic structure, parting to moderate medium blocky; hard, firm; few very fine roots; common fine pores; few patchy clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; clear wavy boundary.

Btk—60 to 72 inches; pink (5YR 8/4) clay loam, pink (5YR 7/4) moist; moderate medium subangular blocky structure; hard, friable; common fine pores; about 45 percent of the soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

*Site No. 2*

Soil Type: Sherm clay loam

Location: Dallam County, Texas; in a cultivated field 300 ft north of irrigation well, 0.5 mi east and 1.5 mi north of Farm Road 297, and 18.3 mi east of its intersection with U.S. Highway 385 in Dalhart.

Pedon Description:

Sample No. S81TX111-1-(1-7)

Ap—0 to 7 inches; brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; weak medium granular and subangular blocky structure; hard, friable; many fine roots; few fine pores; dense plow pan is present in lower 2 inches; mildly alkaline; clear smooth boundary.

Btl—7 to 17 inches; brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; extremely hard, extremely firm; common fine roots; few very fine pores; thin continuous clay films; few vertical cracks; mildly alkaline; gradual smooth boundary.

Bt2—17 to 26 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; common fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt3—26 to 38 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; moderate medium blocky structure; slightly hard, friable; few fine roots; common fine pores; thin continuous clay film; common threads and films of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Ab—38 to 48 inches; brown (7.5YR 5/2) clay loam, brown (7.5YR 4/2) moist; moderate medium subangular blocky structure; slightly hard, friable; few fine roots; common fine pores; calcareous; mildly alkaline; gradual smooth boundary.

Btbl—48 to 60 inches; reddish brown (5YR 5/4) clay loam, reddish brown (5YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium blocky; hard, firm; few fine roots in upper part; common pores; thin continuous clay films; calcareous; mildly alkaline; gradual smooth boundary.

Btb2—60 to 74 inches;

yellowish red (5YR 5/6) clay loam, yellowish red (5YR 4/6) moist; weak coarse prismatic structure, parting to moderate medium blocky; hard, firm; common fine pores; thin continuous clay films; calcareous; moderately alkaline.

*Site No. 3*

Soil Type: Sherm silty clay loam

Location: Moore County, Texas; in a cultivated field 800 ft east of unpaved county road, 0.9 mi north of Farm Road 281, 1.3 mi east of its intersection with U.S. Highway 287 in Etter.

Pedon Description:

Sample No. S81TX341-1-(1-5)

Ap—0 to 6 inches, brown (7.5YR 4/2) silty clay loam, dark brown (7.5YR 3/2) moist; weak fine granular and medium subangular blocky structure; slightly hard, friable; many fine and medium roots; common pores; moderately alkaline; clear smooth boundary.

Bt1—6 to 19 inches, dark brown (7.5YR 4/2) silty clay, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; few wedge-shaped peds; few small stress surfaces; extremely hard, extremely firm; many fine roots; few very fine pores; thin continuous clay films; few vertical cracks; mildly alkaline; gradual smooth boundary.

Bt2—19 to 34 inches, brown (7.5YR 5/4) silty clay loam, brown (7.5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few small stress surfaces; common fine roots; few very fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Bt3—34 to 54 inches; reddish brown (5YR 5/4) clay loam, reddish brown (5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; common patchy clay films; few threads, films, and small concretions of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Btk—54 to 72 inches, pink (7.5YR 8/4) silty clay loam, pink (7.5YR 7/4) moist; weak coarse platy and moderate medium blocky structure; very hard, friable; few fine pores; about 55 percent of the soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

*Site No. 4*

Soil Type: Sherm clay

Location: Texas County, Oklahoma; in a cultivated field, 300 ft east of State Highway 136 and 2.05 mi south of its intersection with U.S. Highway 54 in Guymon.

Pedon Description:

Sample No. S81OK70-1-(1-5)

Ap—0 to 6 inches; dark grayish brown (10YR 4/2) clay, very dark grayish brown (10YR 3/2) moist; weak fine granular and subangular blocky structure; hard, friable; many roots and incorporated residue; moderately alkaline; clear smooth boundary.

Bt1—6 to 20 inches; dark grayish brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate medium blocky structure; extremely hard, extremely firm; few small stress surfaces; common fine roots; few fine pores; thin continuous clay films; few vertical cracks; moderately alkaline; gradual smooth boundary.

Bt2—20 to 38 inches; brown (10YR 5/3) clay loam, brown (10YR 4/3) moist; moderate medium blocky structure; very hard, very firm; common fine roots; few fine pores; common clay films; few small concretions of calcium carbonate that are hard and pitted; calcareous; moderately alkaline; gradual smooth boundary.

Btb1—38 to 63 inches; brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; weak coarse prismatic structure, parting to moderate medium blocky; hard, firm; few fine roots; few fine pores; few patchy clay films; few fine black concretions; few threads, films, and small concretions of calcium carbonate; calcareous; moderately alkaline; gradual smooth boundary.

Btb2—63 to 72 inches; grayish brown (10YR 5/2) silty clay loam, dark grayish brown (10YR 4/2) moist; weak coarse prismatic structure, parting to moderate medium blocky; slightly hard, friable; common fine pores; few threads and films of calcium carbonate; calcareous; moderately alkaline.

*Site No. 5*

Soil Type: Sherm clay loam

Location: Sherman County, Texas; in a cultivated field 300 ft west of Farm Road 2104, 2.0 mi south of U.S. Highway 54, 3.0 mi southwest of its intersection with U.S. Highway 287 in Stratford.

Pedon Description:

Sample No. S81TX421-1-(1-6)

Ap—0 to 6 inches; brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; weak fine granular and subangular blocky structure; hard, friable; many roots; dense plowpan is present in lower 2 inches; mildly alkaline; clear smooth boundary.

Bt1—6 to 17 inches; brown (7.5YR 4/2) clay loam, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; extremely hard, extremely firm; common fine roots; few fine pores; thin continuous clay films; few small vertical cracks; mildly alkaline; gradual smooth boundary.

Bt2—17 to 27 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; common fine roots; thin continuous clay films; few threads and films of calcium carbonate; calcareous; moderately alkaline; gradual smooth boundary.

Bt3—27 to 36 inches; brown (7.5YR 5/4) clay loam, brown (7.5YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium blocky; hard, firm; few fine roots;

common fine pores; few patchy clay films; few threads, films and small concretions of calcium carbonate; calcareous; moderately alkaline; clear smooth boundary.

Bt4—36 to 44 inches; reddish brown (5YR 5/4) clay loam, reddish brown (5YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium blocky; very hard, very firm; few fine roots; few fine pores; common patchy clay films; few threads, films, and small concretions of calcium carbonate; calcareous; moderately alkaline; gradual smooth boundary.

Btk—44 to 72 inches; pink (7.5YR 8/4) clay, pink (7.5YR 7/4) moist; weak coarse platy structure, parting to moderate medium blocky; very hard, firm; common fine pores; about 20 percent of the soil mass consists of soft masses and weakly cemented concretions of calcium carbonate; calcareous; moderately alkaline.

*Site No. 6*

Soil Type: Sherm silty clay loam

Location: Moore County, Texas; in a cultivated field 200 ft east of private road, 1.05 mi north of paved county road, 1.0 mi west of Farm Road 1060 at a point 4.0 mi north of its intersection with State Highway 152, 16.0 mi east of Dumas.

Pedon Description:

Sample No. S81TX341-2-(1-5)

Ap—0 to 7 inches; dark reddish gray (5YR 4/2) silty clay loam, dark reddish brown (5YR 3/2) moist; weak fine granular and subangular blocky structure; hard, friable; many roots; moderately alkaline; clear smooth boundary.

Bt1—7 to 19 inches; dark reddish brown (5YR 3/2) silty clay, dark reddish brown (5YR 2/2) moist; moderate medium blocky structure; few small stress surfaces; extremely hard, extremely firm; common fine roots; few fine pores; thin continuous clay films; few vertical cracks; calcareous; moderately alkaline; gradual smooth boundary.

Bt2—19 to 35 inches; reddish brown (5YR 4/4) clay, reddish brown (5YR 3/4) moist; moderate medium blocky structure; few small stress surfaces; extremely hard, extremely firm; few fine roots; few fine pores; thin continuous clay films; calcareous; moderately alkaline; gradual smooth boundary.

Bt3—35 to 58 inches; brown (7.5YR 5/4) silty clay, brown (7.5YR 4/4) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; moderately alkaline; clear wavy boundary.

Btk—58 to 74 inches; pink (7.5YR 8/4) silty clay loam, pink (7.5YR 7/4) moist; weak coarse platy structure, parting to moderate medium blocky; very hard, friable; very few fine roots in upper 2 inches; about 50 percent of the soil mass consists of weakly cemented concretions of calcium carbonate; calcareous; moderately alkaline.

*Site No. 7*

Soil Type: Sherm silty clay

Location: Hansford County, Texas; in a cultivated field, 2,500 ft west of State Highway 136, 8.7 mi north of Gruver.

Pedon Description:

Sample No. S82TX195-1-(1-6)

Ap—0 to 6 inches; dark brown (7.5YR 4/2) silty clay, dark brown (7.5YR 3/2) moist; weak fine granular and moderate medium subangular blocky structure; hard, friable; common roots; common pores; dense plowpan present in lower part; mildly alkaline; clear smooth boundary.

Bt1—6 to 18 inches; dark brown (7.5YR 4/2) silty clay, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; few wedge-shaped peds; few small stress surfaces; extremely hard, very firm; common fine roots; few fine pores; thin continuous clay films; mildly alkaline; gradual smooth boundary.

Bt2—18 to 26 inches; brown (10YR 5/3) silty clay, brown (10YR 4/3) moist; moderate medium blocky structure; few small stress surfaces; very hard, firm; few fine roots; few fine pores; thin continuous clay films; calcareous; moderately alkaline; gradual smooth boundary.

Bt3—26 to 39 inches; brown (7.5YR 5/4) silty clay loam, brown (7.5YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium subangular blocky structure; hard, firm; few fine roots; few very fine pores; few patchy clay films; common threads and films of calcium carbonate; calcareous; moderately alkaline; gradual smooth boundary.

Bt4—39 to 53 inches; brown (7.5YR 5/4) silty clay, brown (7.5YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium subangular blocky; few fine roots; few very fine pores; few patchy clay films; few threads and films of calcium carbonate; calcareous; moderately alkaline; clear smooth boundary.

Btk—53 to 76 inches; pink (7.5YR 8/4) silty clay loam, pink (7.5YR 7/4) moist; weak coarse platy structure, parting to moderate medium blocky structure; very hard, friable; common fine pores; about 45 percent of the soil mass consists of soft masses and concretions of calcium carbonate; calcareous; moderately alkaline.

*Site No. 8*

Soil Type: Sherm silty clay loam

Location: Hansford County, Texas; in a cultivated field 3,200 ft east of a paved county road, 3.6 mi south of State Highway 15, at a point 1.3 mi northeast of its junction with U.S. Highway 207 in Spearman.

Pedon Description:

Sample No. S82TX195-2-(1-6)

Ap—0 to 6 inches; dark brown (7.5YR 4/2) silty clay loam, dark brown (7.5YR 3/2) moist;

weak granular and moderate medium subangular blocky structure; hard, friable; many fine roots; common fine pores; mildly alkaline; clear smooth boundary.

Bt1—6 to 20 inches; dark brown (7.5YR 4/2) silty clay loam, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; extremely hard, very firm; common fine roots; few very fine pores; thin continuous clay films; few small stress surfaces; moderately alkaline; gradual smooth boundary.

Bt2—20 to 37 inches; brown (10YR 5/3) silty clay loam, brown (10YR 4/3) moist; moderate medium blocky structure; extremely hard, very firm; few fine roots; few very fine pores; thin continuous clay films; few small stress surfaces; calcareous; moderately alkaline; clear smooth boundary.

Ab—37 to 50 inches; brown (7.5YR 5/4) silty clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; very hard, firm; few fine roots; few very fine pores; few threads, films, and small concretions of calcium carbonate; calcareous; moderately alkaline; clear smooth boundary.

Btb1—50 to 60 inches, reddish yellow (5YR 6/6) silty clay loam, yellowish red (5YR 5/6) moist; weak coarse prismatic structure, parting to moderate medium blocky structure; hard, friable; few fine roots; few patchy clay films; common very fine pores; common threads and films of calcium carbonate; calcareous; moderately alkaline; gradual smooth boundary.

Btb2—60 to 93 inches; reddish yellow (5YR 6/8) silty clay loam, yellowish red (5YR 5/8) moist; weak coarse prismatic structure, parting to moderate medium blocky; hard, friable; few fine roots to 76 inches; few patchy clay films; common very fine pores; common threads, films, and small concretions of calcium carbonate; calcareous; moderately alkaline.

*Site No. 9*

Soil Type: Sherm silty clay loam

Location: Beaver County, Oklahoma; in a cultivated field 500 ft north of unpaved county road, 11.8 mi east of U.S. Highway 83 at a point 0.25 mi north of the Texas-Oklahoma state line.

Pedon Description:

Sample No. S81OK4-1-(1-6)

Ap—0 to 7 inches; dark brown (7.5YR 4/2) silty clay loam, dark brown (7.5YR 3/2) moist; weak fine granular and subangular blocky structure; hard, friable; many fine and medium roots; mildly alkaline; clear smooth boundary.

Bt1—7 to 19 inches; brown (7.5YR 4/2) silty clay, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; few small stress surfaces; extremely hard, extremely firm; many fine roots; a few fine pores; thin continuous clay films; few vertical cracks; mildly alkaline; gradual smooth boundary.

Bt2—19 to 36 inches; brown (10YR 5/3) silty clay, brown (10YR 4/3) moist; moderate medium blocky structure; few small stress surfaces; extremely hard, extremely firm; few fine roots; few fine pores; few threads and films of calcium carbonate; calcareous; mildly alkaline; clear smooth boundary.

Ab—36 to 43 inches; brown (10YR 4/3) silty clay loam, dark brown (10YR 3/3) moist; moderate medium subangular blocky structure; hard, friable; few fine roots; common fine pores; few threads, films and weakly cemented concretions of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Btb1—43 to 59 inches; brown (7.5YR 5/4) silty clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm; few fine roots; common fine pores; few patchy clay films; calcareous; mildly alkaline; gradual smooth boundary.

Btb2—59 to 72 inches; brown (7.5YR 5/4) silty clay loam, brown (7.5YR 4/4) moist; moderate medium subangular blocky structure; hard, firm; common patchy clay films; few fine pores; mildly alkaline.

*Site No. 10*

Soil Type: Sherm silty clay loam

Location: Ochiltree County, Texas; in a cultivated field 100 ft south of unpaved county road, 2.2 mi west of U.S. Highway 83 at a point 5.6 mi south of its intersection with State Highway 15 in Perryton.

Pedon Description:

Sample No. S82TX357-1-(1-6)

Ap—0 to 8 inches; dark brown (7.5YR 4/2) silty clay loam, dark brown (7.5YR 3/2) moist; weak fine granular and subangular blocky structure; hard, friable; many fine roots and incorporated residue; mildly alkaline; clear smooth boundary.

Bt1—8 to 24 inches; brown (7.5YR 4/2) silty clay, dark brown (7.5YR 3/2) moist; moderate medium blocky structure; few small stress surfaces; extremely hard, extremely firm; common fine roots; few fine pores; thin continuous clay films; few vertical cracks; mildly alkaline; gradual smooth boundary.

Bt2—24 to 38 inches; brown (7.5YR 5/2) silty clay, brown (7.5YR 4/2) moist; moderate medium blocky structure; few small stress surfaces; extremely hard, extremely firm; few fine roots; few fine pores; thin continuous clay films; few vertical cracks; mildly alkaline; clear smooth boundary.

Ab—38 to 51 inches; brown (10YR 5/3) silty clay, brown (10YR 4/3) moist; moderate medium subangular blocky structure; hard, firm; few fine roots; few fine pores; few threads and films of calcium carbonate; calcareous; mildly alkaline; gradual smooth boundary.

Btb1—51 to 63 inches; yellowish brown (10YR 5/4) silty clay loam, dark yellowish brown (10YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium blocky; very hard, firm; few fine roots; few fine pores; common patchy clay films; calcareous; mildly alkaline; gradual smooth boundary.

Btb2—63 to 76 inches; brown (7.5YR 5/4) silty clay loam, brown (7.5YR 4/4) moist; weak coarse prismatic structure, parting to moderate medium blocky; very hard, firm; occasional very fine roots; few fine pores; common patchy clay films; calcareous; mildly alkaline.

*Site No. 11*

Soil Type: Sherm clay loam

Location: Dallam County, Texas; in a cultivated field, 1,000 ft south of Farm Road 695, 21 mi east of U.S. Highway 54, at a point 5.2 mi northeast of its intersection with U.S. Highway 385 in Dalhart.

Pedon Description:

Sample No. S84TX111-1-(1-5)

Ap—0 to 7 inches; reddish brown (5YR 4/3) clay loam, dark reddish brown (5YR 3/3) moist; weak fine granular and subangular blocky structure; hard, friable; many roots; mildly alkaline; clear smooth boundary.

Bt1—7 to 20 inches; reddish brown (5YR 4/3) clay loam, dark reddish brown (5YR 3/3) moist; moderate medium blocky structure; few small stress surfaces; extremely hard, extremely firm; common fine roots; few fine pores; thin continuous clay films; few vertical cracks; calcareous; mildly alkaline; gradual smooth boundary.

Bt2—20 to 32 inches; reddish brown (5YR 5/3) clay loam, reddish brown (5YR 4/3) moist; moderate medium blocky structure; few small stress surfaces; extremely hard, extremely firm; few fine roots; few fine pores; thin continuous clay films; calcareous; mildly alkaline; gradual smooth boundary.

Bt3—32 to 47 inches; yellowish red (5YR 5/6) silty clay loam, yellowish red (5YR 4/6) moist; moderate medium blocky structure; very hard, very firm; few fine roots; few fine pores; thin continuous clay films; few threads and films of calcium carbonate; calcareous; mildly alkaline; clear wavy boundary.

Btk—47 to 80 inches; pink (5YR 7/4) silty clay loam, light reddish brown (5YR 6/4) moist; weak coarse platy structure, parting to moderate medium blocky; very hard, friable; very few fine roots in upper 2 inches; about 50 percent of the soil mass consists of weakly cemented concretions of calcium carbonate; calcareous; moderately alkaline.

Based on the field descriptions, profiles at the various sites differed mainly in thickness, color, and texture of the different horizons; depth to the calcic horizon or to a buried horizon; and presence or absence of buried horizons. Table 4 indicates which profiles are present at the different sites.

The Ap horizon is 6 to 7 inches thick at all sites except at Site 10, where it was 8 inches thick. Color is brown at Sites 1, 2, 3, and 5; dark grayish brown at Site 4; dark reddish gray at Site 6; reddish brown at Site 11; and dark brown at Sites 7, 8, 9, and 10. Surface textures are clay loam at Sites 1, 2, 5; and 11; silty clay at Site 7; silty clay loam at Sites 3, 6, 8, 9, and 10; and clay at Site 4. This horizon represents mainly the plow layer. The differences in thickness and local differences in texture possibly resulted from mixing the upper layers in plowing.

The Bt1 horizon is mainly 12 to 14 inches thick. But its thickness is 10 inches at Site 2, 11 inches at Site 5, and 16 inches at Site 10. Texture is primarily silty clay but is clay at Site 1; clay loam at Sites 2, 4, 5, and 11; and silty clay loan at Site 8. Colors are mainly brown, but range to dark grayish brown at Site 4; dark reddish gray at Site 6; dark brown at Sites 3, 7, and 8; and dark reddish brown at Site 11.

The Bt2 horizon is commonly 14 to 17 inches thick, but thickness varies from 8 inches at Site 7 to 18 inches at Site 4. Texture is clay loam at Sites 1, 2, 4, 5, and 11; silty clay loam at Site 3 and 8; clay at Site 6; and silty clay at Sites 7, 9, and 10. Color is brown except at Sites 6 and 11, where it is reddish brown.

The Bt3 horizon is present at Sites 1, 2, 3, 5, 6, 7, and 11. Thickness is commonly 12 to 20 inches but is 8 inches at Site 1, 9 inches at Site 5, and 23 inches at Site 6. Texture is mainly clay loam but is silty clay loam at Site 7 and 11 and silty clay at Site 6. Color is commonly brown but is yellowish red at Site 11 and reddish brown at Site 3.

The Bt4 horizon is present at Sites 1, 5, and 7. Thickness is commonly 8 to 14 inches but is 24 inches at Site 1. Texture is dominantly clay loam. Color is brown at Site 7, reddish brown at Site 5, and yellowish red at Site 1.

Buried profiles, or horizons, are present at depths of 36 to 39 inches in Sites 2, 4, 8, 9, and 10. These layers have readily discernable features in the form of colors, textures, or structure that combine to exhibit sharp contrast with overlying horizons. The sand and silt fractions

TABLE 4. HORIZONS IDENTIFIED IN SHERM SOIL PROFILES AT THE VARIOUS SAMPLING SITES

| Site | County, state | Ap | Bt1 | Bt2 | Bt3 | Bt4 | Ab | Btb1 | Btb2 | Btk |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Hartley, Texas | X | X | X | X | X | | | | X |
| 2 | Dallam, Texas | X | X | X | X | | X | X | X | |
| 3 | Moore, Texas | X | X | X | X | | | | | X |
| 4 | Texas, Oklahoma | X | X | X | | | | X | X | |
| 5 | Sherman, Texas | X | X | X | X | X | | | | X |
| 6 | Moore, Texas | X | X | X | X | | | | | X |
| 7 | Hansford, Texas | X | X | X | X | X | | | | X |
| 8 | Hansford, Texas | X | X | X | | | X | X | X | |
| 9 | Beaver, Oklahoma | X | X | X | | | X | X | X | |
| 10 | Ochiltree, Texas | X | X | X | | | X | X | X | |
| 11 | Dallam, Texas | X | X | X | X | | | | | X |

of buried profiles are reddish yellow. Colors of the sand and silt fractions in the upper horizons are light gray or light brownish gray. A clear boundary commonly is present between buried horizons and overlying layers. In sites where an Ab horizon is not readily observable, the boundary between a Btb1 and the overlying horizon is usually gradual.

The Btb horizons are commonly brown, reddish brown, or yellowish red, but colors range to dark yellowish brown and dark grayish brown at Sites 4 and 10, respectively. Textures are clay loam at Site 2 and silty clay loam at Sites 4, 8, 9, and 10.

Btk horizons are present in Sites 1, 3, 5, 6, 7, and 11. Thickness ranges from 12 inches to more than 28 inches. Color is primarily pink, but is light reddish brown at Site 11. Texture is clay loam at Site 1 and silty clay loam at Sites 3, 6, 7, and 11. Calcium carbonate content commonly is 45 to 55 percent by volume but is 22 percent at Site 5.

Other than horizon thickness, color, and texture, most profile conditions that were determined by the field descriptions were similar for all sites for the Ap, Bt1, and Bt2 horizons. The slight differences among sites should have no major influence on soil and crop management practices, except that the dense plowpan present in the Ap horizon at Sites 2, 5, and 7 could adversely affect water infiltration and plant root growth.

Below the Bt2 horizon, conditions were more variable because some profiles contained buried horizons. Also, depth to a calcic horizon varied greatly among sites, ranging mostly from 53 to 60 inches when present. However, at Site 5, the calcic horizon was present at a 44-inch depth while no calcic horizon was found at a depth of 72 to 76 inches at Sites 2, 4, 9, and 10, or at 93 inches at Site 8.

## Particle Size Distribution

Results of the particle size distribution analyses are included in Table 5. The weighted mean for sand content was highest at Sites 1, 2, 5, and 11; intermediate at Sites 3 and 4; and lowest at Sites 6, 7, 8, 9, and 10. The mean sand content, in general, decreased from west to east across the region. The size distribution of the sand fraction varied for samples from the different sites as determined by the percent retained on standard sieves (Table 6). No samples contained a high amount of coarse sand, but the amount of fine and very fine sand in the samples, in general, incrased from west to east across the region.

The distribution of sand within the profiles was variable and erratic, especially at Sites 1 through 5 and Site 11. At some of these sites (Sites 1 and 5), maximum sand content was at the surface, but some deeper horizons had similar sand contents. At other sites, maximum sand contents were in deeper horizons (Sites 2, 3, 4, and 11). At Sites 6 through 10, sand contents tended to increase with depth, but some intermediate horizons had lower sand contents than either the Ap or the deep horizons (Sites 7, 9, and 10).

The weighted mean for silt content was lowest at Sites 1, 2, 5, and 11; intermediate at Sites 3, 4, and 6; and highest at Sites 7, 8, 9, and 10. These trends are opposite those for sand content. Silt content was also variable in the profiles, and no horizon had the highest or lowest silt content in all cases.

The weighted mean for clay content varied less among sites than sand and silt contents, ranging from a low of 32.7 percent at Site 2 to a high of 43.8 percent at Site 6. Clay content usually was highest in the Bt1 and-or Bt2 horizons, except at Site 4,

TABLE 5. CHARACTERISTICS OF THE SHERM SOIL AT THE STUDY SITES

| Site, county, state, and Sample no. | Hor | Depth | Sand | Silt | Clay | Texture | O.M. | pH | B.D. | $CaCo_3$ equiv | Water content at bars potential -1/3[2] | -15 | Plant-avail water | | | Adjusted to 60-in depth[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | in | % | | | | % | | g/cm³ | % | % by volume | | % | in/in | in/hor | |
| Site 1—Hartley, Texas | | | | | | | | | | | | | | | | |
| S81TX205-1-1 | Ap | 0-6 | 35.2 | 33.2 | 31.6 | Clay loam | 1.45 | 7.75 | 1.26[1] | — | 29.5 | 19.2 | 10.3 | 0.103 | 0.62 | |
| -2 | Bt1 | 6-18 | 23.6 | 32.8 | 43.6 | Clay | 0.93 | 7.65 | 1.53 | — | 37.9 | 22.8 | 15.1 | 0.151 | 1.81 | |
| -3 | Bt2 | 18-28 | 20.5 | 39.8 | 39.7 | Clay loam | 0.63 | 7.60 | 1.62 | — | 34.4 | 20.6 | 13.8 | 0.138 | 1.38 | |
| -4 | Bt3 | 28-36 | 26.7 | 37.9 | 35.4 | Clay loam | 0.39 | 7.60 | 1.63 | — | 30.1 | 19.9 | 10.2 | 0.102 | 0.82 | |
| -5 | Bt4 | 36-60 | 35.8 | 30.5 | 33.7 | Clay loam | 0.23 | 7.50 | 1.51 | — | 27.1 | 17.4 | 9.7 | 0.097 | 2.33 | |
| -6 | Btk | 60-72 | 29.9 | 40.9 | 29.2 | Clay loam | 0.25 | 7.90 | 1.46 | 45.25 | — | — | — | — | — | |
| Weighted mean[4] | | | 29.5 | 33.7 | 36.7 | — | 0.58 | 7.59 | 1.52 | — | 31.1 | 19.5 | 11.6 | 0.116 | — | |
| Profile total—in | | | — | — | — | — | — | — | — | — | — | — | — | — | 6.96 | 6.96 |
| Site 2—Dallam, Texas | | | | | | | | | | | | | | | | |
| S81TX111-1-1 | Ap | 0-7 | 36.0 | 32.4 | 31.6 | Clay loam | 1.75 | 7.70 | 1.26[1] | — | 31.1 | 20.2 | 10.9 | 0.109 | 0.76 | |
| -2 | Bt1 | 7-17 | 32.8 | 29.3 | 37.9 | Clay loam | 0.84 | 7.60 | 1.58 | — | 33.8 | 18.6 | 15.2 | 0.152 | 1.52 | |
| -3 | Bt2 | 17-26 | 43.9 | 25.4 | 30.7 | Clay loam | 0.39 | 7.60 | 1.55 | — | 26.0 | 16.9 | 9.1 | 0.091 | 0.82 | |
| -4 | Bt3 | 26-38 | 46.0 | 27.6 | 26.4 | Clay loam | 0.36 | 7.50 | 1.49 | — | 22.2 | 17.6 | 4.6 | 0.046 | 0.55 | |
| -5 | Ab | 38-48 | 22.0 | 45.6 | 32.4 | Clay loam | 0.45 | 7.70 | 1.51 | — | 27.2 | 19.3 | 7.9 | 0.079 | 0.79 | |
| -6 | Btb1 | 48-60 | 33.0 | 32.1 | 34.9 | Clay loam | 0.34 | 7.70 | 1.64 | — | 29.6 | 19.0 | 10.6 | 0.106 | 1.27 | |
| -7 | Btb2 | 60-74 | 40.3 | 24.9 | 34.8 | Clay loam | 0.23 | 7.90 | 1.69 | — | — | — | — | — | — | |
| Weighted mean | | | 36.6 | 30.7 | 32.7 | — | 0.54 | 7.68 | 1.55 | — | 28.0 | 18.5 | 9.5 | 0.095 | — | |
| Profile total—in | | | — | — | — | — | — | — | — | — | — | — | — | | 5.71 | 5.71 |

TABLE 5. CONTINUED

| Site, county, state, and Sample no. | Hor | Depth | Sand | Silt | Clay | Texture | O.M. | pH | B.D. | $CaCo_3$ equiv | Water content at bars potential -1/3[2] | Water content at bars potential -15 | Plant-avail water | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | | | Adjusted to 60-in |
| | | in | | % | | | % | | g/cm[3] | % | % by volume | | % | in/in | in/hor | depth[3] |
| Site 3—Moore, Texas | | | | | | | | | | | | | | | | |
| S81TX341-1-1 | Ap | 0-6 | 16.8 | 47.2 | 36.0 | Silty clay loam | 2.17 | 7.90 | 1.26[1] | — | 36.4 | 24.3 | 12.1 | 0.121 | 0.73 | |
| -2 | Bt1 | 6-19 | 12.0 | 41.3 | 46.7 | Silty clay | 1.13 | 7.80 | 1.41 | — | 40.2 | 22.4 | 17.8 | 0.178 | 2.31 | |
| -3 | Bt2 | 19-34 | 13.9 | 48.0 | 38.1 | Silty clay loam | 0.56 | 7.80 | 1.51 | — | 31.9 | 20.5 | 11.4 | 0.114 | 1.71 | |
| -4 | Bt3 | 34-54 | 26.5 | 41.2 | 32.3 | Clay loam | 0.30 | 7.70 | 1.58 | — | 27.0 | 21.5 | 5.5 | 0.055 | 1.10 | |
| -5 | Btk | 54-72 | 18.2 | 56.2 | 25.1 | Silty clay loam | 0.24 | 7.90 | 1.38 | 58.48 | — | — | — | — | — | |
| | Weighted mean | | 18.4 | 43.8 | 37.8 | — | 0.80 | 7.77 | 1.48 | — | 32.6 | 21.8 | 10.8 | 0.108 | — | |
| | Profile total—in | | — | — | — | — | — | — | — | — | — | — | — | — | 5.85 | 6.18 |
| Site 4—Texas, Oklahoma | | | | | | | | | | | | | | | | |
| S81OK70-1-1 | Ap | 0-6 | 22.9 | 36.7 | 40.4 | Clay | 1.87 | 7.90 | 1.26[1] | — | 38.1 | 26.1 | 12.0 | 0.120 | 0.72 | |
| -2 | Bt1 | 6-20 | 28.6 | 32.6 | 38.8 | Clay loam | 1.07 | 7.90 | 1.50 | — | 34.9 | 25.1 | 9.8 | 0.098 | 1.37 | |
| -3 | Bt2 | 20-38 | 22.3 | 39.0 | 38.7 | Clay loam | 0.56 | 7.90 | 1.60 | — | 33.1 | 24.5 | 8.6 | 0.086 | 1.55 | |
| -4 | Btb1 | 38-63 | 17.1 | 44.6 | 38.3 | Silty clay loam | 0.38 | 7.90 | 1.58 | — | 31.7 | 23.5 | 8.2 | 0.082 | 2.05 | |
| -5 | Btb2 | 63-72 | 16.2 | 47.4 | 36.4 | Silty clay loam | 0.34 | 7.90 | 1.60 | — | — | — | — | — | — | |
| | Weighted mean | | 21.0 | 40.6 | 38.4 | — | 0.68 | 7.90 | 1.55 | — | 33.4 | 24.4 | 9.0 | 0.090 | — | |
| | Profile total—in | | — | — | — | — | — | — | — | — | — | — | — | — | 5.69 | 5.44 |
| Site 5—Sherman, Texas | | | | | | | | | | | | | | | | |
| S81TX421-1-1 | Ap | 0-6 | 34.4 | 32.4 | 33.2 | Clay loam | 1.70 | 7.60 | 1.26[1] | — | 32.0 | 21.0 | 11.0 | 0.110 | 0.66 | |
| -2 | Bt1 | 6-17 | 23.8 | 40.0 | 36.2 | Clay loam | 0.86 | 7.80 | 1.48 | — | 31.8 | 20.9 | 10.9 | 0.109 | 1.20 | |
| -3 | Bt2 | 17-27 | 22.9 | 37.3 | 39.8 | Clay loam | 0.46 | 7.90 | 1.56 | — | 33.1 | 24.3 | 8.8 | 0.088 | 0.88 | |
| -4 | Bt3 | 27-36 | 34.8 | 31.6 | 33.6 | Clay loam | 0.32 | 7.90 | 1.57 | — | 27.9 | 19.6 | 8.3 | 0.083 | 0.75 | |
| -5 | Bt4 | 36-44 | 33.1 | 31.4 | 35.5 | Clay loam | 0.32 | 7.90 | 1.47 | — | 28.5 | 16.0 | 12.5 | 0.125 | 1.00 | |
| -6 | Btk | 44-72 | 26.8 | 33.2 | 40.0 | Clay | 0.16 | 8.00 | 1.57 | 21.63 | — | — | — | — | — | |
| | Weighted mean | | 29.0 | 35.1 | 36.0 | — | 0.68 | 7.83 | 1.48 | — | 30.7 | 20.5 | 10.2 | 0.102 | — | |
| | Profile total—in | | — | — | — | — | — | — | — | — | — | — | — | — | 4.49 | 6.49 |
| Site 6—Moore, Texas | | | | | | | | | | | | | | | | |
| S81TX341-2-1 | Ap | 0-7 | 10.5 | 52.7 | 36.8 | Silty clay loam | 1.94 | 7.90 | 1.26[1] | — | 40.7 | 28.2 | 12.5 | 0.125 | 0.88 | |
| -2 | Bt1 | 7-19 | 9.9 | 46.6 | 43.5 | Silty clay | 1.06 | 8.00 | 1.54 | — | 33.1 | 24.3 | 9.4 | 0.094 | 1.13 | |
| -3 | Bt2 | 19-35 | 14.0 | 38.1 | 47.9 | Clay | 0.67 | 8.00 | 1.62 | — | 40.5 | 24.6 | 15.9 | 0.159 | 2.54 | |
| -4 | Bt3 | 35-58 | 13.5 | 41.8 | 44.7 | Silty clay | 0.35 | 8.00 | 1.38 | — | 34.5 | 22.2 | 12.3 | 0.123 | 2.46 | |
| -5 | Btk | 58-74 | 16.8 | 47.5 | 35.7 | Silty clay loam | 0.33 | 7.90 | 1.75 | 54.17 | — | — | — | — | — | |
| | Weighted mean | | 12.6 | 43.6 | 43.8 | — | 0.78 | 7.99 | 1.46 | — | 36.7 | 24.0 | 12.7 | 0.127 | — | |
| | Profile total—in | | — | — | — | — | — | — | — | — | — | — | — | — | 7.01 | 7.26 |
| Site 7—Hansford, Texas | | | | | | | | | | | | | | | | |
| S82TX195-1-1 | Ap | 0-6 | 8.3 | 50.1 | 41.6 | Silty clay | 2.14 | 7.70 | 1.26[1] | — | 40.3 | 27.7 | 12.6 | 0.126 | 0.76 | |
| -2 | Bt1 | 6-18 | 5.6 | 51.2 | 43.2 | Silty clay | 0.97 | 7.80 | 1.44 | — | 37.1 | 24.5 | 12.6 | 0.126 | 1.51 | |
| -3 | Bt2 | 18-26 | 5.8 | 53.9 | 40.3 | Silty clay | 0.61 | 7.90 | 1.53 | — | 33.9 | 22.8 | 11.1 | 0.111 | 0.89 | |
| -4 | Bt3 | 26-39 | 9.3 | 51.9 | 38.8 | Silty clay loam | 0.54 | 7.90 | 1.39 | — | 31.3 | 21.7 | 9.6 | 0.096 | 1.25 | |
| -5 | Bt4 | 39-53 | 13.1 | 44.1 | 42.8 | Silty clay | 0.33 | 8.00 | 1.44 | — | 33.6 | 15.3 | 18.3 | 0.183 | 2.56 | |
| -6 | Btk | 53-76 | 17.1 | 48.6 | 34.3 | Silty clay loam | 0.22 | 8.00 | 1.77 | 45.25 | — | — | — | — | — | |
| | Weighted mean | | 8.8 | 49.8 | 41.4 | — | 0.77 | 7.88 | 1.42 | — | 34.6 | 21.5 | 13.1 | 0.131 | — | |
| | Profile total—in | | — | — | — | — | — | — | — | — | — | — | — | — | 6.97 | 8.25 |

(continued on next page)

TABLE 5. CONTINUED

| Site, county, state, and Sample no. | Hor | Depth | Sand | Silt | Clay | Texture | O.M. | pH | B.D. | $CaCo_3$ equiv | Water content at bars potential -1/3[2] | Water content at bars potential -15 | Plant-avail water | | | Adjusted to 60-in depth[3] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | in | | % | | | % | | g/cm[3] | % | % by volume | | % | in/in | in/hor | |
| Site 8—Hansford, Texas | | | | | | | | | | | | | | | | |
| S82TX195-2-1 | Ap | 0-6 | 8.8 | 54.6 | 36.6 | Silty clay loam | 2.85 | 7.80 | 1.26[1] | — | 40.2 | 26.9 | 13.3 | 0.133 | 0.80 | |
| -2 | Bt1 | 6-20 | 8.2 | 52.2 | 39.6 | Silty clay loam | 1.22 | 7.90 | 1.47 | — | 36.0 | 25.6 | 10.4 | 0.104 | 1.46 | |
| -3 | Bt2 | 20-37 | 8.5 | 51.9 | 39.6 | Silty clay loam | 0.80 | 7.90 | 1.59 | — | 34.9 | 23.9 | 11.0 | 0.110 | 1.87 | |
| -4 | Ab | 37-50 | 19.0 | 44.1 | 36.9 | Silty clay loam | 0.53 | 7.90 | 1.59 | — | 31.6 | 19.2 | 12.4 | 0.124 | 1.61 | |
| -5 | Btb1 | 50-60 | 19.7 | 45.8 | 34.5 | Silty clay loam | 0.28 | 7.80 | 1.35 | — | 26.5 | 15.7 | 10.8 | 0.108 | 1.08 | |
| -6 | Btb2 | 60-93 | 18.6 | 47.9 | 33.5 | Silty clay loam | 0.27 | 7.80 | 1.24 | — | — | — | — | — | — | |
| Weighted mean | | | 14.7 | 49.0 | 36.3 | — | 0.71 | 7.84 | 1.40 | — | 33.6 | 22.2 | 11.4 | 0.114 | — | |
| Profile total—in | | | — | — | — | — | — | — | — | — | — | — | — | — | 6.82 | 6.82 |
| Site 9—Beaver, Oklahoma | | | | | | | | | | | | | | | | |
| S81OK4-1-1 | Ap | 0-7 | 11.9 | 56.5 | 31.6 | Silty clay loam | 2.33 | 7.70 | 1.26[1] | — | 34.0 | 22.1 | 11.9 | 0.119 | 0.83 | |
| -2 | Bt1 | 7-19 | 9.6 | 47.2 | 43.2 | Silty clay | 1.20 | 7.80 | 1.43 | — | 38.2 | 24.9 | 13.3 | 0.133 | 1.60 | |
| -3 | Bt2 | 19-36 | 7.7 | 49.1 | 43.2 | Silty clay | 0.65 | 7.80 | 1.54 | — | 36.3 | 24.6 | 11.7 | 0.117 | 1.99 | |
| -4 | Ab | 36-43 | 8.4 | 53.2 | 38.4 | Silty clay loam | 0.55 | 7.70 | 1.42 | — | 31.3 | 22.0 | 9.3 | 0.093 | 0.65 | |
| -5 | Btb1 | 43-59 | 8.9 | 52.1 | 39.0 | Silty clay loam | 0.58 | 7.50 | 1.26 | — | 30.5 | 19.3 | 11.2 | 0.112 | 1.79 | |
| -6 | Btb2 | 59-72 | 13.1 | 46.9 | 40.0 | Silty clay | 0.48 | 7.30 | 1.14 | — | — | — | — | — | — | |
| Weighted mean | | | 9.5 | 50.2 | 40.1 | — | 0.85 | 7.62 | 1.35 | — | 34.2 | 22.6 | 11.6 | 0.116 | — | |
| Profile total—in | | | — | — | — | — | — | — | — | — | — | — | — | — | 6.86 | 7.04 |
| Site 10—Ochiltree, Texas | | | | | | | | | | | | | | | | |
| S82TX357-1-1 | Ap | 0-8 | 9.3 | 61.0 | 29.7 | Silty clay loam | 3.03 | 7.50 | 1.26[1] | — | 36.1 | 23.1 | 13.0 | 0.130 | 1.04 | |
| -2 | Bt1 | 8-24 | 6.3 | 50.2 | 43.5 | Silty clay | 1.41 | 7.50 | 1.51 | — | 40.1 | 26.1 | 14.0 | 0.140 | 2.24 | |
| -3 | Bt2 | 24-38 | 4.9 | 51.5 | 43.6 | Silty clay | 0.89 | 7.70 | 1.62 | — | 38.5 | 26.9 | 11.6 | 0.116 | 1.62 | |
| -4 | Ab | 38-51 | 4.1 | 53.7 | 42.2 | Silty clay | 0.85 | 7.70 | 1.41 | — | 35.5 | 21.0 | 14.5 | 0.145 | 1.89 | |
| -5 | Btb1 | 51-63 | 6.9 | 55.6 | 37.5 | Silty clay loam | 0.68 | 7.70 | 1.44 | — | 31.5 | 21.3 | 10.2 | 0.102 | 1.22 | |
| -6 | Btb2 | 63-76 | 10.4 | 51.5 | 38.1 | Silty clay loam | 0.57 | 7.70 | 1.39 | — | — | — | — | — | — | |
| Weighted mean | | | 6.8 | 53.3 | 40.0 | — | 1.13 | 7.64 | 1.46 | — | 36.6 | 23.9 | 12.7 | 0.127 | — | |
| Profile total—in | | | — | — | — | — | — | — | — | — | — | — | — | — | 8.01 | 7.70 |
| Site 11—Dallam, Texas | | | | | | | | | | | | | | | | |
| S84TX111-1-1 | Ap | 0-7 | 37.3 | 31.9 | 30.8 | Clay loam | 1.61 | 6.80 | 1.26[1] | — | 29.8 | 19.7 | 10.1 | 0.101 | 0.71 | |
| -2 | Bt1 | 7-20 | 35.4 | 26.8 | 37.8 | Clay loam | 0.70 | 7.40 | 1.49 | — | 32.2 | 22.2 | 10.0 | 0.100 | 1.30 | |
| -3 | Bt2 | 20-32 | 38.5 | 22.7 | 38.8 | Clay loam | 0.31 | 7.60 | 1.45 | — | 30.7 | 20.4 | 10.3 | 0.103 | 1.24 | |
| -4 | Bt3 | 32-47 | 52.2 | 13.2 | 34.6 | Silty clay loam | 0.19 | 7.80 | 1.60 | — | 28.3 | 23.0 | 4.7 | 0.407 | 0.71 | |
| -5 | Btk | 47-80 | 51.1 | 14.5 | 34.4 | Silty clay loam | 0.14 | 8.10 | 1.62 | 49.52 | — | — | — | — | — | |
| Weighted mean | | | 41.8 | 22.1 | 36.0 | — | 0.63 | 7.83 | 1.48 | — | 30.2 | 21.6 | 8.6 | 0.086 | — | |
| Profile total—in | | | — | — | — | — | — | — | — | — | — | — | — | — | 3.96 | 4.57 |

[1]Bulk density of the Ap horizon was estimated from values obtained from other studies because this horizon was the loosened tillage layer and core sampling was not possible when the samples were obtained.

[2]Water contents at the -1/3-bar matric potential were calculated by Equation 1, Table 7, of Unger (1975).

[3]Adjusted to 60-inch depth for all horizons by adding or subtracting plant-available water based on water retention of the horizon above or the horizon occurring at the 60-inch depth.

[4]The calcic horizon, when present, was not included in the weighted mean calculations. For water content, weighted means were calculated only to the depth to which data are presented.

TABLE 6. SAND CONTENT AND SIZE DISTRIBUTION OF THE SAND IN SHERM SOIL

| Site, county, & state | Hor | Depth | Total sand | Percent of sand retained on standard sieves with openings of (mm) 0.850 (#20) | 0.425 (#40) | 0.250 (#60) | 0.150 (#100) | 0.106 (#140) | 0.053 (#270) |
|---|---|---|---|---|---|---|---|---|---|
| | | in | % | % | | | | | |
| Site 1— | Ap | 0-6 | 35.2 | 0.2 | 5.5 | 20.4 | 18.3 | 23.5 | 32.1 |
| Hartley, Texas | Bt1 | 6-18 | 23.6 | 0.6 | 6.7 | 24.2 | 16.1 | 21.2 | 31.2 |
| | Bt2 | 18-28 | 20.5 | 2.4 | 7.2 | 22.6 | 14.9 | 19.5 | 33.4 |
| | Bt3 | 28-36 | 26.7 | 1.0 | 6.2 | 24.1 | 17.5 | 20.6 | 30.6 |
| | Bt4 | 36-60 | 35.8 | 0.4 | 4.8 | 23.1 | 18.3 | 22.2 | 31.2 |
| | Btk | 60-72 | 29.9 | 2.8 | 5.9 | 21.7 | 17.4 | 22.0 | 30.2 |
| | Weighted mean[1] | | 31.3 | 0.8 | 5.8 | 23.1 | 17.2 | 21.5 | 31.6 |
| Site 2— | Ap | 0-7 | 36.0 | 0.1 | 5.4 | 24.4 | 17.6 | 20.7 | 31.8 |
| Dallam, Texas | Bt1 | 7-17 | 32.8 | 0.1 | 5.4 | 22.9 | 17.9 | 21.8 | 31.9 |
| | Bt2 | 17-26 | 43.9 | 0.3 | 5.9 | 27.1 | 19.1 | 20.0 | 27.6 |
| | Bt3 | 26-38 | 46.0 | 0.2 | 10.0 | 33.5 | 17.3 | 16.9 | 22.1 |
| | Ab | 38-48 | 22.0 | 1.1 | 7.1 | 22.5 | 15.6 | 19.4 | 34.3 |
| | Btb1 | 48-60 | 33.0 | 0.5 | 6.8 | 23.9 | 15.7 | 17.0 | 36.1 |
| | Btb2 | 60-74 | 40.3 | 0.3 | 8.4 | 31.3 | 19.4 | 19.9 | 20.7 |
| | Weighted mean | | 36.6 | 0.4 | 7.2 | 27.0 | 17.5 | 19.2 | 28.7 |
| Site 3— | Ap | 0-6 | 16.8 | 0.0 | 1.9 | 10.7 | 14.9 | 24.3 | 48.2 |
| Moore, Texas | Bt1 | 6-19 | 12.0 | 0.2 | 2.1 | 11.1 | 14.1 | 22.2 | 50.3 |
| | Bt2 | 19-34 | 13.9 | 2.1 | 3.2 | 10.4 | 14.7 | 23.2 | 46.4 |
| | Bt3 | 34-54 | 26.5 | 0.9 | 1.8 | 9.5 | 16.1 | 25.9 | 45.8 |
| | Btk | 54-72 | 18.2 | 1.7 | 2.3 | 11.8 | 17.4 | 27.5 | 39.3 |
| | Weighted mean | | 18.4 | 1.0 | 2.3 | 10.3 | 15.1 | 24.1 | 47.3 |
| Site 4— | Ap | 0-6 | 22.9 | 0.1 | 5.7 | 18.6 | 14.2 | 23.5 | 37.9 |
| Texas, Oklahoma | Bt1 | 6-20 | 28.6 | 0.3 | 5.0 | 14.1 | 10.3 | 16.2 | 54.1 |
| | Bt2 | 20-38 | 22.3 | 0.6 | 5.7 | 15.2 | 10.8 | 15.7 | 52.0 |
| | Btb1 | 38-63 | 17.1 | 1.5 | 5.3 | 13.2 | 10.2 | 14.6 | 55.2 |
| | Btb2 | 63-72 | 16.2 | 1.0 | 4.8 | 11.7 | 9.3 | 13.4 | 59.8 |
| | Weighted mean | | 21.0 | 0.9 | 5.3 | 14.1 | 10.6 | 15.8 | 53.3 |
| Site 5— | Ap | 0-6 | 34.4 | 0.4 | 2.4 | 13.2 | 20.7 | 27.7 | 35.6 |
| Sherman, Texas | Bt1 | 6-17 | 23.8 | 0.4 | 3.0 | 11.5 | 16.5 | 23.5 | 45.1 |
| | Bt2 | 17-27 | 22.9 | 7.2 | 6.4 | 10.3 | 14.0 | 23.3 | 38.8 |
| | Bt3 | 27-36 | 34.8 | 5.6 | 7.5 | 12.1 | 15.9 | 23.8 | 35.1 |
| | Bt4 | 36-44 | 33.1 | 2.1 | 4.7 | 13.1 | 20.5 | 29.2 | 30.4 |
| | Btk | 44-72 | 26.8 | 1.0 | 3.0 | 11.4 | 19.3 | 28.9 | 36.4 |
| | Weighted mean | | 29.0 | 3.3 | 4.9 | 11.9 | 17.1 | 25.1 | 37.1 |
| Site 6— | Ap | 0-7 | 10.5 | 0.7 | 1.8 | 4.0 | 6.1 | 17.4 | 70.0 |
| Moore, Texas | Bt1 | 7-19 | 9.9 | 0.0 | 2.0 | 5.2 | 8.1 | 22.2 | 62.5 |
| | Bt2 | 19-35 | 14.0 | 1.7 | 2.8 | 5.6 | 8.5 | 22.7 | 58.7 |
| | Bt3 | 35-58 | 13.5 | 2.5 | 2.9 | 5.8 | 8.9 | 23.4 | 56.5 |
| | Btk | 58-74 | 16.8 | 2.3 | 3.1 | 6.4 | 9.7 | 25.7 | 52.8 |
| | Weighted mean | | 12.6 | 1.6 | 2.5 | 5.3 | 8.1 | 21.8 | 60.6 |
| Site 7— | Ap | 0-6 | 8.3 | 0.0 | 4.7 | 8.7 | 7.7 | 17.4 | 61.5 |
| Hansford, Texas | Bt1 | 6-18 | 5.6 | 0.7 | 3.5 | 6.2 | 5.2 | 13.6 | 70.8 |
| | Bt2 | 18-26 | 5.8 | 2.7 | 6.2 | 7.9 | 6.7 | 14.4 | 62.1 |
| | Bt3 | 26-39 | 9.3 | 3.0 | 7.9 | 9.2 | 7.6 | 15.6 | 56.7 |
| | Bt4 | 39-53 | 13.1 | 1.6 | 8.4 | 10.3 | 7.7 | 15.1 | 56.9 |
| | Btk | 53-76 | 17.1 | 2.5 | 6.6 | 10.2 | 9.5 | 19.8 | 51.4 |
| | Weighted mean | | 8.8 | 1.7 | 6.4 | 8.6 | 7.0 | 15.0 | 61.3 |
| Site 8— | Ap | 0-6 | 8.8 | 0.0 | 2.0 | 4.1 | 4.3 | 17.5 | 72.1 |
| Hansford, Texas | Bt1 | 6-20 | 8.2 | 1.1 | 1.8 | 2.6 | 2.5 | 15.6 | 76.4 |
| | Bt2 | 20-37 | 8.5 | 1.5 | 2.5 | 3.8 | 3.5 | 17.6 | 71.1 |
| | Ab | 37-50 | 19.0 | 2.2 | 2.4 | 3.4 | 3.9 | 20.5 | 67.6 |
| | Btb1 | 50-60 | 19.7 | 1.8 | 2.5 | 3.5 | 3.7 | 20.1 | 68.4 |
| | Btb2 | 60-93 | 18.6 | 1.2 | 2.0 | 3.3 | 3.3 | 20.1 | 70.1 |
| | Weighted mean | | 14.7 | 1.4 | 2.2 | 3.4 | 3.4 | 18.9 | 70.8 |

(continued on next page)

where it was highest in the Ap horizon. Clay content usually was lowest in the Ap horizon, except that it was lowest in the Bt3 at Site 2; Btb2 at Sites 4 and 8; and Btk at Sites 3, 6, and 7.

## Bulk Density

Bulk density of the Ap horizon (plow layer) was not determined because this horizon was loosened by tillage and remained loose at the time of sampling. Other studies, however, have shown that the bulk density of this horizon is highly variable, depending on type and recency of tillage. For this study, a bulk density of 1.26 g/cm$^3$ was assumed for the Ap horizon at all sites (Table 5). This value is the average for the Ap horizon in studies by Taylor et al. (1963), Unger (1969, 1972), and Unger et al. (1973) on Pullman clay loam, which is a similar soil. The assumed value is provided for calculating the available water content of this horizon in a subsequent section.

Bulk density of the Bt1 horizon ranged from 1.41 g/cm$^3$ at Site 3 to 1.58 g/cm$^3$ at Site 2. Densities usually were highest in the Bt2 or Bt3 horizons except at Site 2, where it was highest in the Btb2 horizon (1.69 g/cm$^3$), and at Sites 6, 7, and 11 where it was highest in the Btk horizon. Some unusually low bulk densities at horizons other than the Ap were 1.38 g/cm$^3$ in the Bt3 at Site 6; 1.39 g/cm$^3$ in the Bt3 at Site 7; 1.35 and 1.24 g/cm$^3$ in the Btb1 and Btb2, respectively, at Site 8; 1.26 and 1.14 g/cm$^3$ in the Btb1 and Btb2, respectively, at Site 9; and 1.39 g/cm$^3$ in the Btb2 at Site 10. The low bulk densities in the lower part of the profile suggest that root growth would not be impeded by soil density in these horizons if roots could readily penetrate the horizons above.

Bulk densities at the different sites are not high enough to prevent root penetration if the soil water content is adequately high, but some reduction in root penetration may occur. Resistance to root penetration is influenced by soil strength, which is a function of soil bulk density and water content (Taylor and Gardner, 1963). In their study with Amarillo

TABLE 6. CONTINUED

| Site, county, & state | Hor | Depth | Total sand | Percent of sand retained on standard sieves with openings of (mm) 0.850 (#20) | 0.425 (#40) | 0.250 (#60) | 0.150 (#100) | 0.106 (#140) | 0.053 (#270) |
|---|---|---|---|---|---|---|---|---|---|
| | | in | % | % | | | | | |
| Site 9— Beaver, Oklahoma | Ap | 0-7 | 11.9 | 0.2 | 1.7 | 2.5 | 2.4 | 9.9 | 83.3 |
| | Bt1 | 7-19 | 9.6 | 0.6 | 1.9 | 1.7 | 1.7 | 8.2 | 85.9 |
| | Bt2 | 19-36 | 7.7 | 3.4 | 2.9 | 1.8 | 1.6 | 5.6 | 84.7 |
| | Ab | 36-43 | 8.4 | 4.8 | 3.5 | 1.8 | 1.5 | 4.8 | 83.6 |
| | Btb1 | 43-59 | 8.9 | 1.7 | 1.9 | 1.7 | 1.8 | 9.7 | 83.2 |
| | Btb2 | 59-72 | 13.1 | 0.6 | 1.4 | 2.0 | 2.2 | 12.7 | 81.1 |
| | Weighted mean | | 9.5 | 1.9 | 2.2 | 1.9 | 1.8 | 8.6 | 83.7 |
| Site 10— Ochiltree, Texas | Ap | 0-8 | 9.3 | 0.0 | 2.4 | 2.7 | 2.7 | 11.9 | 80.3 |
| | Bt1 | 8-24 | 6.3 | 1.2 | 1.9 | 2.0 | 2.0 | 10.1 | 82.8 |
| | Bt2 | 24-38 | 4.9 | 2.3 | 2.9 | 2.5 | 2.5 | 9.3 | 80.5 |
| | Ab | 38-51 | 4.1 | 8.4 | 5.7 | 4.4 | 2.7 | 8.3 | 70.5 |
| | Btb1 | 51-63 | 6.9 | 3.9 | 2.8 | 2.1 | 2.2 | 14.0 | 75.0 |
| | Btb2 | 63-76 | 10.4 | 1.1 | 1.7 | 2.2 | 2.8 | 16.9 | 75.3 |
| | Weighted mean | | 6.8 | 2.9 | 2.9 | 2.6 | 2.5 | 11.6 | 77.5 |
| Site 11— Dallam, Texas | Ap | 0-7 | 37.3 | 0.2 | 6.1 | 24.2 | 17.8 | 20.2 | 31.5 |
| | Bt1 | 7-20 | 35.4 | 0.3 | 4.0 | 18.0 | 18.4 | 27.0 | 32.3 |
| | Bt2 | 20-32 | 38.5 | 0.9 | 4.9 | 22.2 | 21.1 | 24.6 | 26.3 |
| | Bt3 | 32-47 | 52.2 | 0.2 | 5.4 | 23.8 | 21.6 | 25.1 | 23.9 |
| | Btk | 47-80 | 51.1 | 0.1 | 5.5 | 23.4 | 21.5 | 25.0 | 24.5 |
| | Weighted mean | | 37.1 | 0.5 | 5.0 | 21.8 | 20.0 | 24.8 | 28.0 |

[1]Calic horizons, where present, were not included in calculating the weighted means.

fine sandy loam, Taylor and Gardner (1963) showed that some roots penetrated the soil at a bulk density of 1.75 g/cm$^3$ if the soil matric potential was -½ bar or higher. For bulk densities equal to or less than 1.65 g/cm$^3$, some root penetration occurred when the matric potential was -⅔ bar or higher. Resistance to root penetration at similar soil matric potentials and bulk densities may be different in Sherm soils than in Amarillo soils. And the bulk densities measured by core samples may be considerably different than those determined on individual soil clods. With core sampling, the bulk density represents an average density of the sampled volume, which includes the soil and the shrinkage cracks that develop as the soil dries. For individual clods, shrinkage cracks are not included in the sample volume. The density of the clods, therefore, may be considerably higher than those obtained by core sampling and may be high enough to prevent root penetration in some horizons of the soil.

## Organic Matter

Soil organic matter content was highest in the Ap horizon at all sites and usually decreased progressively with soil depth (Table 5). An exception was at Site 2, where the Ab horizon had a higher organic matter content than the Bt2 and Bt3 horizons above it. For the Ap horizon, the organic matter content was lowest at Site 1 (1.45 percent) and next lowest at Site 11 (1.61 percent). These sites also had high sand contents in the Ap horizon. High organic matter contents (2.14 to 3.03 percent) were found in the Ap horizon at Sites 7 to 10, all of which had 50 percent or more silt in the Ap horizon. Based on weighted means for the entire profile, organic matter contents ranged from 0.54 percent at Site 2 to 1.13 percent at Site 10. A significant positive relationship between soil organic matter and silt content was previously established for Texas soils (Unger, 1975).

## pH

Soil pH (Table 5) varied relatively little ($\leq$0.30 pH unit) throughout the profiles at most sites. Exceptions were at Site 2, where the range was 0.40 unit, and at Site 9, where the range was 0.50 unit. In general, there were no consistent trends related to soil depth except at Sites 5, 6, 7, 10, and 11, where pH increased with soil depth. The lowest weighted mean pH (7.59) occurred at Site 1. The highest (8.10) and lowest (7.30) pH for a horizon was at Site 11.

The soil was mildly to moderately alkaline in all cases (see profile descriptions), which corresponds with pH values of more than 7.0. Although alkaline, the pH is not high enough to suggest that field crops usually grown would be adversely affected. But plants sensitive to alkaline conditions may be affected and, therefore, may require special treatments for good growth.

## Calcium Carbonate ($CaCO_3$) Equivalent

The $CaCO_3$ equivalent, which refers to the neutralizing power of the soil material, was determined for calcic horizons in the soil profiles. The $CaCO_3$ equivalents ranged from 21.6 percent at Site 5 to 58.5 percent at Site 3. But even soil with such $CaCO_3$ equivalents is considered low grade in value for liming purposes (Lawton and Kurtz, 1957).

## Water Retention

Cores were not obtained from the Ap horizon because this horizon was the loosened tillage layer. Therefore, water contents at -⅓ and -15 bars matric potentials for this horizon (Table 5) were calculated by equations developed by Unger (1975). The equations are based on the soil bulk density, organic matter content, and clay content of the horizon. The water contents at -⅓-bar matric potential for other horizons were also calculated by the equation of Unger (1975) because values determined for this study were generally lower than expected or previously determined values for this soil. The calculated values should be valid because the correlation coefficients obtained when developing the equations were significant at the 0.1 percent level (Unger, 1975). For other than the Ap horizon, determined values are given for water contents at -15 bars matric potential.

The water contents (Table 5) at -⅓-bar matric potential are calculated on a volume basis. The -15-bar values on a volume basis were obtained by multiplying the determined values (weight basis) by the soil bulk density. The plant-available water (PAW) contents for the different horizons are the differences between the -⅓-bar and -15-bar values, presented on a percent-by-volume basis. Water contents for individual horizons were obtained by multiplying the horizon thickness by the percent PAW. Totals for the profile are summations of the values for individual horizons.

Plant-available water contents were determined only for horizons above the calcic horizon or to a depth (horizon change) at or near 60 inches when a calcic horizon was not encountered (Sites 2, 4, 8, 9, and 10). This depth was used because roots of most crops do not penetrate the calcic horizon or extend beyond the 60-inch depth if the calcic horizon is not present. Because of its shallow depth (47 inches), the profile at Site 11 had the lowest total PAW storage capacity (3.96 inches). On a weighted mean basis, the storage capacity per inch of soil at Site 11 was also lowest. The highest weighted mean storage capacity per inch of soil was at Site 7. But because of a depth of only 53 inches, total PAW at Site 7 was only 6.97 inches compared with 7.01 and 8.01 inches at Sites 6 and 10, respectively. The last two profiles had greater total water storage capacity because their depths were greater.

To obtain a better comparison of water retention among profiles, all profiles were adjusted to a 60-inch depth with the assumption that any calcic horizon had a water holding capacity equal to that of the horizon immediately above it. Profile depths greater than 60 inches were disregarded.

For profiles adjusted to a 60-inch depth, maximum PAW holding capacity of 8.25 inches occurred at Site 7. The minimum was 4.57 inches at Site 11. Other capacities ranged from 5.44 to 7.70 inches. In general, the higher the sand content, the lower the PAW holding capacity. These results are similar to expectations and previous studies (Unger, 1975; Unger and Pringle, 1981).

Even though total PAW holding capacities varied from site to site, the results suggest that no major differences in management are needed to use the soil effectively as a water storage reservoir for crops. First, the values in Table 5 should serve only as a guide because actual amounts of soil water storage and subsequent use by plants are influenced by many factors, and field values seldom correspond with laboratory values. Second, crops with well-developed root systems often extract soil water to lower values than the reported -15-bar values. Probably the most important factor with respect to water holding capacity is that the soil be managed so that the storage reservoir is readily refilled with water from precipitation or irrigation. This requires that conditions be maintained for effective infiltration of water into the soil. Soil management is further discussed in a later section.

## Water Infiltration

The results of water infiltration measurements in Table 7 show the amount of water infiltrated at 10 min and at 12 and 20 hrs, and the infiltration rates at times from 10 min to 20 hrs after water application starts. The values presented are the means for one, two, or three determinations at each site under varying surface, plow layer, and residue conditions. (See remarks, Table 7).

Based on individual sets of observations, the amount of water infiltrated at 10 min was highest at Site 3 (2.04 inches) and lowest at Site 6 (0.38 inch). At 12 hrs, water infiltrated was highest at Site 6 (12.22 inches) and lowest (1.03 inches) at Site 4. Sites 3 and 6 had the highest (15.66 inches) and lowest (1.41 inches) infiltration, respectively, at 20 hrs.

One factor that apparently had a major influence on infiltration was the bulk density of the Ap horizon, which was determined when infiltration measurements were made (Table 7). At Site 3, where total infiltration was 15.66 inches at 20 hrs, the bulk density was 1.10 g/cm$^3$. At Site 6, which had the lowest total infiltration at 20 hrs (1.41 inches), the bulk density was 1.71 g/cm$^3$. Total infiltration at 20 hrs was also low (1.44 inches) at Sites 4 and 7, where the bulk density of the Ap horizon was 1.74 and 1.76 g/cm$^3$, respectively.

A close relationship between bulk density of the Ap horizon and water infiltration was confirmed by results of multiple regression analyses (Table 8). Total infiltration and infiltration rate at 10 min and 20 hrs were significantly influenced by bulk density of the Ap horizon, with a ranking of 1 in all cases. Clay and sand contents were also significantly related to total infiltration and infiltration rate at 10 min but not at 20 hrs. Thickness, silt content, and organic matter content of the Ap horizon did not significantly influence infiltration at 10 min or 20 hrs.

Characteristics of the Bt1 horizon (other than bulk density determined when infiltration was measured) were not significantly related to total infiltration or infiltration rate, determined by multiple regression analyses (data not shown). But total infiltration and infiltration rate at 10 min were significantly related to organic matter content and bulk density of the Bt2 horizon (Table 8). The effect of silt content was not significant. When silt content was omitted from the analyses, the coefficient of correlation for the relationship among infiltration, organic matter content, and bulk density was not significant. For the entire profile involving weighted mean values for the different characteristics, neither total infiltration nor infiltration rate at 10 min and at 20 hrs was significantly related to the profile characteristics.

For analyses involving only the bulk densities of the Ap and Bt1 horizons as determined when infiltration was measures, the density of both horizons was significantly

TABLE 7. AMOUNT AND RATE OF WATER INFILTRATION AND RELATED DATA FROM SHERM SOILS

| Site location, & number of observations | Soil bulk density till zone | Soil bulk density Bt hor | Cumulative infiltration at 10 min | Cumulative infiltration at 12 hr | Cumulative infiltration at 20 hr | Infiltration rate at 10 min | Infiltration rate at 30 min | Infiltration rate at 1 hr | Infiltration rate at 2 hr | Infiltration rate at 5 hr | Infiltration rate at 12 hr | Infiltration rate at 20 hr | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | g/cm³ | | in | | | in/hr | | | | | | | |
| Site 1 Hartley, Texas | | | | | | | | | | | | | |
| 3 | 1.69 | 1.61 | 0.75 | 2.19 | 2.57 | 1.80 | 0.39 | 0.24 | 0.18 | 0.09 | 0.04 | 0.04 | Tillage pan present; no crust; after harvest. |
| 1 | 1.44 | 1.52 | 0.95 | 4.08 | 5.76 | 2.90 | 0.60 | 0.30 | 0.25 | 0.25 | 0.20 | 0.20 | Tillage pan fractured by plowing; no crust; preplant. |
| 2 | 1.62 | 1.52 | 1.00 | 4.34 | 5.11 | 2.88 | 0.85 | 0.65 | 0.40 | 0.25 | 0.12 | 0.09 | Wheel track furrow; no crust; preplant. |
| Site 2 Dallam, Texas | | | | | | | | | | | | | |
| 1 | 1.63 | 1.43 | 0.85 | 3.07 | 3.43 | 2.04 | 0.60 | 0.25 | 0.25 | 0.15 | 0.06 | 0.04 | Wheel track furrow; no crust; preplant. |
| 2 | 1.21 | 1.35 | 1.47 | 8.67 | 10.80 | 4.32 | 1.50 | 0.83 | 0.70 | 0.60 | 0.35 | 0.27 | Unpacked furrow; no crust; preplant. |
| Site 3 Moore, Texas | | | | | | | | | | | | | |
| 1 | 1.10 | 1.54 | 2.04 | 6.17 | 7.20 | 5.76 | 1.44 | 0.90 | 0.50 | 0.24 | 0.15 | 0.15 | Loose surface following sweep tillage; no crust; preplant. |
| 2 | 1.10 | 1.28 | 1.80 | 11.90 | 15.66 | 6.48 | 2.56 | 1.31 | 1.05 | 0.74 | 0.53 | 0.40 | Loose surface following sweep tillage; no crust; preplant. |
| Site 4 Texas, Oklahoma | | | | | | | | | | | | | |
| 1 | 1.70 | 1.63 | 1.00 | 1.70 | 1.80 | 2.40 | 0.72 | 0.08 | 0.06 | 0.02 | 0.02 | 0.016 | Loose, fluffy surface; tillage pan present at 2-inch depth; no crust; preplant. |
| 2 | 1.74 | 1.60 | 0.60 | 1.03 | 1.44 | 1.26 | 0.60 | 0.11 | 0.07 | 0.03 | 0.01 | 0.008 | Loose, fluffy surface; tillage pan present at 2-inch depth; no crust preplant. |
| Site 5 Sherman, Texas | | | | | | | | | | | | | |
| 1 | 1.65 | 1.53 | 0.84 | 3.19 | 3.81 | 1.80 | 0.60 | 0.45 | 0.25 | 0.18 | 0.10 | 0.08 | Wheel track furrow; no crust; after emergence. |
| 2 | 1.21 | 1.37 | 0.96 | 9.68 | 12.81 | 3.30 | 1.19 | 0.94 | 0.90 | 0.72 | 0.48 | 0.35 | Unpacked furrow; no tillage pan; no crust; after energence. |
| Site 6 Moore, Texas | | | | | | | | | | | | | |
| 2 | 1.10 | 1.41 | 1.00 | 9.77 | 11.88 | 4.32 | 1.60 | 1.40 | 1.08 | 0.74 | 0.36 | 0.25 | Unpacked furrow; no tillage pan; no crust; before first irrigation. |
| 1 | 1.71 | 1.55 | 0.38 | 1.25 | 1.41 | 0.72 | 0.16 | 0.11 | 0.07 | 0.05 | 0.03 | 0.02 | Wheel track furrow; thick crust present. |
| 1 | 1.57 | 1.50 | 1.20 | 4.08 | 4.68 | 2.88 | 1.08 | 1.00 | 0.45 | 0.16 | 0.08 | 0.08 | Tillage pan present at 5-inch depth; crust removed; after harvest. |
| 2 | 1.10 | 1.43 | 1.68 | 12.22 | 14.11 | 6.48 | 3.60 | 2.52 | 1.19 | 0.64 | 0.33 | 0.28 | Tillage pan disturbed; crust removed; after harvest. |

TABLE 7. CONTINUED

| Site location, & number of observations | Soil bulk density till zone | Bt hor | Cumulative infiltration at 10 min | 12 hr | 20 hr | Infiltration rate at 10 min | 30 min | 1 hr | 2 hr | 5 hr | 12 hr | 20 hr | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | g/cm³ | | in | | | in/hr | | | | | | | |
| Site 7 Hansford, Texas | | | | | | | | | | | | | |
| 1 | 1.55 | 1.51 | 1.00 | 4.15 | 5.14 | 2.88 | 0.66 | 0.54 | 0.36 | 0.24 | 0.12 | 0.12 | Unpacked furrow; moist crust present; preplant. |
| 1 | 1.76 | 1.56 | 0.95 | 1.20 | 1.44 | 1.40 | 0.04 | 0.04 | 0.03 | 0.02 | 0.02 | 0.02 | Wheel track furrow; moist crust present; preplant. |
| Site 8 Hansford, Texas | | | | | | | | | | | | | |
| 3 | 1.64 | 1.49 | 1.65 | 4.19 | 4.64 | 2.88 | 0.96 | 0.48 | 0.16 | 0.09 | 0.07 | 0.06 | Tillage pan present; wheat stubble, thin crust present; after harvest. |
| 1 | 1.48 | 1.53 | 1.17 | 6.30 | 7.53 | 3.24 | 1.17 | 1.06 | 0.70 | 0.36 | 0.16 | 0.14 | Wheat stubble on surface; thin crust present; after harvest. |
| 2 | 1.10 | 1.49 | 1.78 | 8.84 | 10.56 | 8.22 | 1.91 | 1.43 | 0.81 | 0.43 | 0.24 | 0.22 | Tillage pan disturbed; wheat stubble; crust removed; after harvest. |
| Site 9 Beaver, Oklahoma | | | | | | | | | | | | | |
| 3 | 1.19 | 1.37 | 1.43 | 10.27 | 12.75 | 5.10 | 2.93 | 2.04 | 1.09 | 0.67 | 0.31 | 0.27 | Moist, settled surface; crust removed following forage sorghum; after harvest. |
| Site 10 Ochiltree, Texas | | | | | | | | | | | | | |
| 1 | 1.52 | 1.41 | 1.32 | 7.27 | 8.28 | 5.76 | 2.02 | 1.44 | 0.77 | 0.43 | 0.16 | 0.13 | Tillage pan present; wheat stubble; no crust; after harvest. |
| 2 | 1.66 | 1.43 | 1.26 | 2.91 | 3.20 | 2.88 | 0.42 | 0.29 | 0.20 | 0.13 | 0.05 | 0.04 | Tillage pan present; wheat stubble; no crust; after harvest. |
| Site 11 Dallam, Texas | | | | | | | | | | | | | |
| 2 | 1.65 | 1.54 | 0.60 | 3.24 | 3.84 | 1.20 | 0.50 | 0.36 | 0.18 | 0.12 | 0.08 | 0.06 | Loose, fluffy surface; tillage pan present; grain sorghum residue on surface. |
| 1 | 1.41 | 1.54 | 0.80 | 4.80 | 6.00 | 1.44 | 0.60 | 0.48 | 0.30 | 0.25 | 0.18 | 0.12 | Loose, fluffy surface; moderate tillage pan development. |

related to total infiltration and infiltration rate at 20 hrs (Table 9). At 10 min, infiltration was significantly related only to the bulk density of the Ap horizon.

Lack of effect of most profile conditions and major effect of bulk density of the Ap horizon on total water infiltration suggest that management practices that influence the plow layer (Ap horizon) density have a major influence on water infiltration and, consequently, on water storage in the profile. Effects of management on tillage zone conditions and, subsequently, on bulk density of the Ap and Bt1 horizon and rate of water infiltration at 20 hrs are shown in Table 10. These results are a summary of the infiltration and related data presented in Table 7. For loose surface soil with residues on the surface and the absence of tillage pans or surface crusts, the infiltration rate at 20 hrs ranged from 0.20 to 0.40 inch/hr. Water infiltration rates decreased as soil density increased, surface residues decreased, soil compaction increased, crusts became evident, and-or tillage pans developed. With severe compaction, for example, the bulk density of the Ap horizon was 1.73 g/cm³ and the in-

TABLE 8. SUMMARY OF MULTIPLE LINEAR REGRESSION ANALYSES ASSOCIATING TOTAL INFILTRATION AND INFILTRATION RATES AT 10 MIN. AND 20 HR. WITH Ap and Bt2 HORIZON CHARACTERISTICS OF SHERM SOIL OBTAINED AT 11 SITES IN TEXAS AND OKLAHOMA. RANKINGS BASED ON STANDARDISED PARTIAL REGRESSION COEFFICIENTS[1] AND LEVELS OF SIGNIFICANCE OF PARTIAL REGRESSION COEFFICIENTS[2] BASED ON t-VALUE ARE ALSO SHOWN.

| Soil horizon and dependent variable | Intercept | Independent variables[3] | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Sand | Silt | Clay | O.M. | BD | SE[4] | R[5] |
| Ap | | Partial regression coefficients | | | | | | |
| Total infiltration in 10 min—in | 4.321 | -0.0168(2)** | — | -0.0336(3)** | — | -1.1111(1)** | 0.265 | 0.805** |
| Total infiltration in 20 hr—in | 30.783 | — | — | — | — | -16.4920(1)** | 1.786 | 0.921** |
| Infiltration rate in 10 min—in/hr | 18.874 | -0.0657(3)** | — | -0.1309(2)** | — | -6.4399(1)** | 0.834 | 0.916** |
| Infiltration rate at 20 hr—in/hr | 0.749 | — | — | — | — | -0.4165(1)** | 5.203 | 0.899** |
| Bt2 | | | | | | | | |
| Total infiltration in 10 min—in | 21.791 | — | -0.0466(3)NS | — | 4.6084(1)* | -13.6183(2)* | 0.215 | 0.864* |
| Infiltration rate in 10 min—in/hr | 86.451 | — | -0.2169(3)NS | — | 20.8030 | -54.8674(2)* | 0.918 | 0.850* |

[1]Rankings are shown in parentheses immediately after partial regression coefficients. Rankings in order from 1 (highest) to 3 (lowest).
[2]Levels of significance of partial regression coefficients are *(0.05), **(0.01), and NS (not significant). These are shown after the rankings.
[3]Independent variables are % sand content, % silt content, % clay content, % organic matter content, and g/cm[3] bulk density.
[4]Standard error of estimate.
[5]Coefficient of correlation. Levels of significance are *(0.05) and **(0.01).

filtration rate was only 0.008 to 0.03 inch/hr.

The differences in water infiltration rate and amount at the various sites may not be representative of all the fields in the vicinity of the particular sites. The prevailing conditions undoubtedly reflect past management on the fields, such as tillage methods, crops grown, and residue management practices. Therefore, farmers should evaluate conditions on their farms and adjust their practices accordingly. For example, if a plowpan is hindering water infiltration, some type of tillage operation, such as chiseling, deep sweep plowing, or even moldboard plowing, may be required to disrupt the plowpan and improve water infiltration and storage in the soil.

## IMPLICATIONS FOR MANAGEMENT

### Plant-Available Water

The total amount of PAW retained in the soil profile was influenced by depth to the calcic horizon (or horizon change at or near 60 inches) and by the water holding capacity of soil in different horizons. Total amounts ranged from 3.96 inches at Site 11 to 8.01 inches at Site 10 (Table 5). Therefore, a crop could extract about twice as much water from soil at Site 10 as at Site 11, provided both profiles were initially filled to capacity with water and the crop's roots permeated and extracted water from the entire soil volume to the depth indicated (Table 5). Both conditions, however, often are not fulfilled under field conditions at all locations.

TABLE 9. SUMMARY OF MULTIPLE LINEAR REGRESSION ANALYSES ASSOCIATING TOTAL INFILTRATION AND INFILTRATION RATES AT 10 MIN AND 20 HR WITH Ap AND Bt1 HORIZON BULK DENSITIES OF SHERM SOILS OBTAINED AT 11 SITES IN TEXAS AND OKLAHOMA. RANKINGS BASED ON STANDARDIZED PARTIAL REGRESSION COEFFICIENTS[1] AND LEVELS OF SIGNIFICANCE OF PARTIAL REGRESSION COEFFICIENTS[2] BASED ON t—VALUE ARE ALSO SHOWN.

| Dependent variable | Intercept | Independent variables[3] | | | |
|---|---|---|---|---|---|
| | | BD of Ap | BD of Bt1 | SE[4] | R[5] |
| | | Partial regression coefficients | | | |
| Total infiltration in 10 min—in | 2.843 | -1.1444(1)** | — | 0.308 | 0.688** |
| Total infiltration in 20 hr—in | 50.901 | -12.6183(1)** | -17.4180(2)** | 1.335 | 0.959** |
| Infiltration rate at 10 min—in/hr | 13.113 | -6.5700(1)** | — | 1.056 | 0.847** |
| Infiltration rate at 20 hr—in/hr | 1.265 | -0.3172(2)** | -0.4466(2)** | 0.043 | 0.937** |

[1]Rankings are shown in parentheses immediately after partial regression coefficients. Rankings in order from 1 (highest) to 2 (lowest).
[2]Levels of significance of partial regression coefficients are *(0.05) and **(0.01). These are shown after the rankings.
[3]Independent variables are g/cm[3] bulk density of Ap and Bt1 horizons.
[4]Standard error of estimate.
[5]Coefficient of correlation. Level of significance (**) is 0.01.

TABLE 10. SUMMARY OF THE EFFECTS OF TILLAGE ZONE CHARACTERISTICS OF SHERM SOILS ON AVERAGE WATER INFILTRATION RATE AT 20 HR.

| Tillage zone conditions (Tilth) | Average in-place bulk density Ap | Average in-place bulk density Bt | Average infiltration rate at 20 hr |
|---|---|---|---|
| | g/cm³ | | in/hr |
| Loose, bulked surface layers with heavy residue on or near soil surface; absence of tillage pans and surface crusts. | 1.15<br>1.17<br>1.21 | 1.32<br>1.38<br>1.47 | 0.31-0.40<br>0.26-0.30<br>0.20-0.25 |
| Loose, bulked surface layers with moderate residue on or near soil surface, and thin, very weak crusts in place. Residual compaction is present in upper Bt horizon. | 1.29 | 1.54 | 0.14-0.15 |
| Settled surface layers with little residue on or near soil surface, and weak crusts in place. Early stages of tillage pan development are evident. | 1.54 | 1.46 | 0.12-0.13 |
| Readily discernable compaction in the form of wheel track furrows or well-developed tillage pans; with or without loose, bulked surface layers and residue on or near the surface. | 1.61 | 1.53 | 0.08-0.09 |
| Readily discernable compaction in the form of tillage pans; with or without residue on or near the surface and loosened surfaces. | 1.65 | 1.49 | 0.04-0.06 |
| Severe compaction in the form of tillage pans; with or without crusts, residues on or near the surface, and loosened surface layers. | 1.73 | 1.59 | 0.008-0.03 |

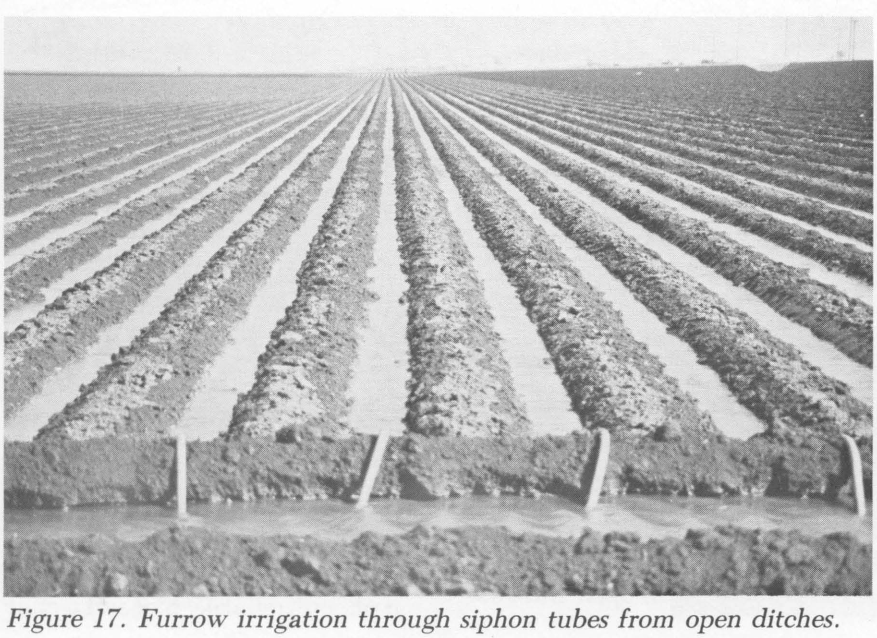

*Figure 17. Furrow irrigation through siphon tubes from open ditches.*

Based on PAW holding capacities (Table 5) and the measured infiltration rates (Table 7), profiles at Sites 2, 3, 5, 6, 8, and 9 could be completely refilled with water (for example, by irrigation) in less than 12 hrs. But other profiles would not be refilled even at 20 hrs. Under the infiltration conditions prevailing at 20 hrs, additional time required to refill the profiles would range from about 9 hrs at Site 5 to about 350 hrs at Site 4. In most cases, prolonging the time of irrigation to fill the profile with water is not practical under the prevailing conditions, and the profiles at some sites normally would not be refilled with water except during prolonged wet periods or occasionally with repeated irrigations. Profiles in most cases would contain about 5 inches or more of PAW when irrigated for 20 hrs (or less in some cases) and would, therefore, provide considerable water for plant use, even though some profiles may not be filled to capacity.

Root penetration into a soil varies with plant species. Sunflower and wheat roots have grown into and used water from the calcic horizon from Pullman clay loam at Bushland. In contrast, sorghum generally uses water from only the upper 4 ft of the soil, thus not fully using all available water when the depth to the calcic horizon is more than 4 ft (Unger and Pringle, 1981). The Pullman soil is similar to the Sherm soil, especially at sites where a calcic horizon is present, and root penetration probably would be similar on both soils. Therefore, even though there are differences in water-holding capacity and soil depth at the different sites, the management required (for example, irrigation frequency) to obtain similar yields with a given amount of water may be nearly identical at all sites, at least for crops that do not root deeply. The water application rate, however, may need to be varied because of infiltration rate differences. Crops that root deeply, tolerate stress, and deplete soil water to low levels would probably perform well on dryland and would require less frequent irrigation (if irrigated) than crops that root less deeply, are sensitive to stress, and fail to extract all PAW. Marked dif-


*Figure 18. Equipment used by Water Conservation District and Soil Conservation Service personnel to evaluate irrigation systems.*

*Figure 19. View of a surge irrigation system.*

ferences in water extraction by sunflower and grain sorghum have occurred on Pullman soil at Bushland. When grown on adjacent fallowed plots, sunflower extracted more water from the soil at all depths than sorghum (Unger and Pringle, 1981). Similar differences would probably occur on Sherm soils.

### Water Application

Furrow irrigation (Figures 13, 17) is widely practiced on Sherm soils, commonly with furrow lengths of one-half mile. Because of the generally low infiltration rates, it is widely believed that deep percolation of water is slight on this soil. But infiltration measurements at the various sites (Table 7) suggest that considerable deep percolation may be occurring at some sites, even when settings are only 12 hrs. Consequently, irrigation requires a knowledge of amount of water applied and soil water storage capacity to make efficient use of the water. Deep percolation should be avoided. To evaluate irrigation practices, assistance is available through the water conservation districts and the Soil Conservation Service (Figure 18). Where excessive deep percolation is a problem under furrow-irrigated conditions, irrigation sets may need to be shortened. Other alternatives are to use higher flow

*Figure 20. Low pressure center-pivot irrigation system.*

*Figure 21. Low pressure irrigation system on furrow-diked and open-furrow land. Note runoff in open furrows.*

rates per furrow with shorter irrigation sets, smooth furrow bottoms for more rapid water advance, or use the surge-irrigation system (Figure 19) that has been evaluated recently in the region. Further water savings can be achieved by using pipes rather than open ditches to convey the water to the irrigation furrows.

On sites where the infiltration rate is low, tailwater runoff may be high from furrow irrigation unless cutback flow rates are used. Some of the tailwater can be recycled through recovery systems, but building the systems and pumping more water adds to production costs.

Pumping costs are higher for sprinkler systems than for furrow irrigation because of the extra head required to pressurize the system. But labor requirements for sprinkler systems, such as center-pivot systems, are lower than for furrow-irrigation systems. The water can also be applied with sprinklers at rates comparable to infiltration rates. In an ideally designed sprinkler system, the water should be applied at a rate slightly less than the infiltration rate. This minimizes the potential for water collecting on the surface and, therefore, water losses by runoff.

High-pressure sprinkler systems apply water over a relatively large area, minimizing runoff problems. But these systems are energy intensive and may result in high evaporative losses of water from the falling droplets or fine spray. Low-pressure sprinklers require less energy but apply water over a smaller area (Figure 20). Evaporative losses of water should be lower, but runoff losses could be higher unless special provisions are made to reduce runoff. Lyle (1979) controlled runoff and used water efficiently with a low-pressure, precision water application system used with furrow dikes (Figure 21). Another possibility would be to add booms with attached nozzles at right angles to the main frame of the sprinkler system, thus applying water to a larger area at the same time.

### Water Infiltration Variation

The data in Table 7 show more than a five fold variation among the observations in total water infiltration at 10 min and even greater difference in infiltration rates at different times. This variation seemed to be most closely related to bulk density of the Ap horizons, but total water infiltration and infiltration rates also varied considerably among measurements within some sites. Such variation resulted from local conditions, such as a surface crust, compaction, and possibly soil cracking, and suggests that water behavior on a given field near the sampling sites may differ considerably from that indicated by the data in Table 7.

Where infiltration is much lower than expected, a compacted zone such as a plow pan may have developed in the soil. Deeper than normal plowing or chiseling while the soil is relatively dry is a possible remedy for overcoming infiltration problems associated with compacted soil layers. Another possible remedy is the use of reduced- or no-tillage cropping systems, which minimize soil compaction because of less traffic across the field, increase infiltration because of surface protection afforded by crop residues (Figure 22), and improve soil conditions because of decaying plant roots (with no-tillage system). Based on the measurements, large variations in infiltration are possible at all sites on Sherm soil. Where problems are suspected, appropriate corrective measures should be taken to increase infiltration where it is too low or decrease it where deep percolation occurs.

### Crop Sequences

Wheat, grain sorghum, corn, sunflower, sugarbeets, alfalfa, and some vegetable crops, such as potatoes (*Solanum tuberosum*) and onions (*Allium cepa*), are adapatable and grown throughout some part or the entire area of Sherm soils. Much of the grain produced in the region is stored in elevators (Figure 23), then transported to area feedlots (Figure 24) or seaports for export to foreign countries. Whether the crops are grown continuously or in rotations depends on such factors as crop prices; water availability; fertilizer cost and availability; weed, insect, and disease problems; and the producers' preferences. When irrigated crops that do not root deeply are grown continuously, some water

*Figure 22. Crop residues maintained on the soil surface are conducive to rapid water infiltration.*

*Figure 23. Grain storage elevator.*

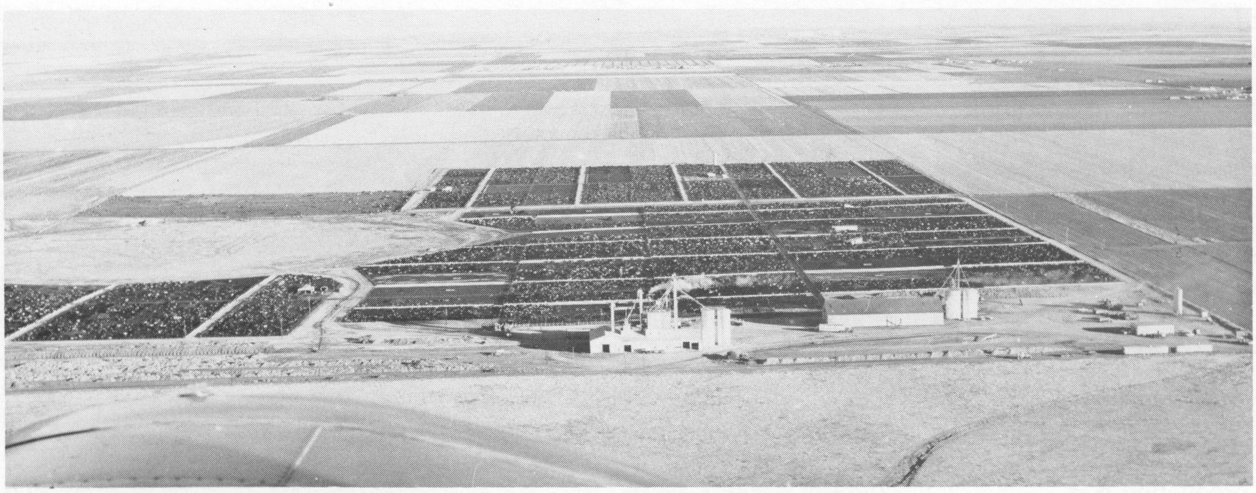

*Figure 24. Cattle in feedlots consume much of the grain produced on Sherm soils. (USDA-Soil Conservation Service photo).*

generally moves beyond the depth of plant rooting and, therefore, reduces water use efficiency for crop production. Unless a deep-rooted crop is subsequently grown, this water may be lost for crop production unless it eventually reaches the aquifer from which it could be pumped again.

Water losses from deep percolation can be minimized by growing deep-rooted crops in rotation with shallower-rooted crops. The effectiveness of deep-rooted crops for extracting water from deep in the profiles is enhanced when these crops are grown without irrigation or with a limited amount of irrigation. In either case, adequate water must be available throughout the profile so that root growth is not restricted by a dry zone of soil.

With water available to a 6-ft depth of Pullman soil at Bushland, dryland grain sorghum used water mainly to a 3-ft depth and only a slight amount from the fourth foot of soil in some years (Unger and Wiese, 1979). In contrast, wheat on dryland used water to a 6-ft depth (Johnson and Davis, 1980), sunflower with limited irrigation used water to a 10-ft depth (Unger, 1978a), and alfalfa used water to a 15-ft depth (Mathers et al., 1975) on Pullman soil when water was available to these depths. Similar responses are expected for these crops on Sherm soils.

*Figure 25. Conservation bench terraces uniformly distribute collected runoff water on the leveled bench portion of the terrace system (photo provided by O.R. Jones, USDA-ARS).*

*Figure 26. Water retained on a furrow-blocked field following 2 inches of rain (photo provided by O.R. Jones, USDA-ARS).*

### Tillage and Cropping Practices

Concern about the steady decline of the water level in the Ogallala

*Figure 27. The amount of residue produced by dryland grain sorghum on Sherm soil generally is low. Note presence of thick surface crust which is enhanced by lack of residue.*

*Figure 28. The amount of residue produced by dryland winter wheat on Sherm soil generally is low.*

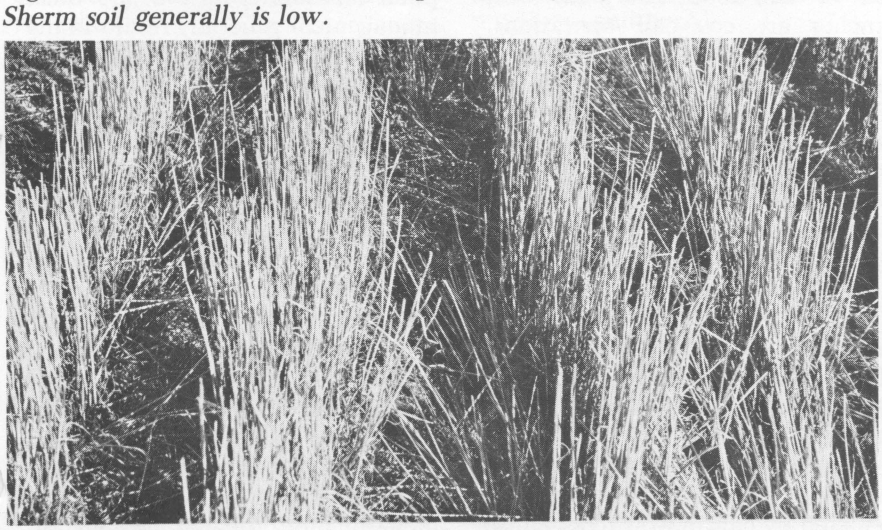

*Figure 29. Residues remaining after harvest of irrigated winter wheat.*

Aquifer, which supplies water to irrigate Sherm soils, and rising energy costs, have caused emphasis on conservation of irrigation water and increased the emphasis on conservation and use of precipitation for crop production. Studies conducted on Pullman soils, which are very similar to Sherm soils, can aid in understanding the effects of conservation practices on Sherm soils.

Under dryland conditions, more water from precipitation was conserved and grain yields were higher where stubble mulch tillage was used instead of one-way disk tillage in continuous wheat or wheat-fallow cropping systems (Johnson and Davis, 1972). Other practices that have conserved water and increased crop yields on dryland are conservation bench terraces (Figure 25) and level bench terraces (Jones, 1975; Jones and Hauser, 1975); narrow benches, narrow conservation benches, and large contour furrows (Jones, 1981); and furrow blocking (Clark and Hudspeth, 1976; Clark and Jones, 1981) (Figure 26). These practices retained potential runoff water where it fell or retained it on a portion of the field, thus increasing the amount of water available for crop use. Little benefit was obtained with respect to reduced evaporation because the residues produced by dryland crops (Figure 27, 28) generally were not adequate to greatly reduce evaporation, even when all residues were maintained on the surface in no-tillage systems (Army et al., 1961; Wiese and Army, 1958; Wiese et. al., 1960, 1967).

In contrast to the lack of response to surface residues for increasing water storage from precipitation in no-tillage systems on dryland, major increases in water storage were obtained when residues from irrigated wheat (Figure 29) were managed on the surface with no-tillage systems compared to working residues into soil with tillage (Musick et al., 1977; Unger et al., 1971; Unger and Wiese, 1979). The additional stored water decreased the amount of irrigation water needed for irrigated grain sorghum (Musick et al., 1977) and resulted in good growth (Figure 30) and yields of dryland grain sorghum (Unger and Wiese, 1979). In a controlled-residue-level study,

e 30. An excellent dryland grain
m crop on land where residues from
revious irrigated winter wheat crop
maintained on the soil surface by no-
methods.*

water storage during fallow and subsequent grain sorghum yields increased as surface residues (wheat) increased from 0 to about 11,000 lbs per acre (Unger, 1978b). Dryland wheat often yields only about 1,500 to 2,500 lbs of residue per acre at Bushland. In contrast, irrigated wheat often yields 4,000 to 6,000 lbs of residue per acre; amounts of 10,000 or more pounds per acre have been obtained in some years (Unger, 1977; Unger et al., 1971).

The residue amounts produced by irrigated wheat are in the range that substantially increased water storage and grain sorghum yields (Unger, 1978b). Therefore, residues from crops, such as irrigated wheat, are a resource that can be managed to increase water use efficiency for crop production on Pullman soil and, by inference, on Sherm soils.

The benefits from surface residues result from greater total infiltration and less evaporation of water. Because of their greater water storage capacity, profiles at Sites 1, 6, 7, 8, 9, and 10 may derive greater benefits from surface residues than those at Sites 2, 3, 4, 5, and 11. Soils with less storage capacity are more readily filled with water because less water is required, provided water infiltration rates are sufficiently high. The greater response to surface residues on Pullman soils at a deep site at Bushland compared with that at a shallower site near Lubbock was verified by Baumhardt (1980), who compared the effects of disk and no-tillage after wheat on water storage during fallow and subsequent growth and yield of grain sorghum. Because rainfall essentially filled the low-capacity profile with water with both tillage methods near Lubbock, sorghum yields were not significantly different because of tillage. At Bushland, where the storage capacity was greater, no-tillage significantly increased grain yields of sorghum over yields with disk tillage when the sorghum was not irrigated. With irrigation, sorghum yields were similar with both tillage treatments.

A benefit from lower evaporation with surface residues is the prolonged time that the surface layer remains wet enough to beneficially influence seed germination. Whereas rapid decreases in surface soil water content from evaporation may cause poor germination on relatively smooth bare soil, the slower evaporation on mulched soils may result in favorable germination of crops.

**Ranching and Livestock Production**

Ranching and livestock production are important agricultural enterprises on the High Plains. Native grassland on Sherm soils covers about 110,000 acres, or 9 percent of their total land area. Most ranches are cow-calf operations, though stocker steers make up a significant percentage of many herds (Figure 31). Usually, these stocker cattle are placed in nearby feedlots for finishing.

On many ranches, the forage produced on rangeland is supplemented by crop stubble (Figure 32) and small grain. In winter, the native forage is often supplemented with protein concentrate. Creep feeding of calves and yearlings to increase market weight is practiced on some ranches.

The native vegetation in many parts of the area has been greatly depleted by continued excessive use (Figure 33). Forage production now may be less than half of the original production. Range productivity can be increased by using management practices that are effective for specific kinds of soils and range sites.

Where climate and topography are similar, differences in the kind and amount of climax vegetation produced on rangeland are related closely to the kind of soil. Effective management is based on the relationships among soils, vegetation, and water.

The typical vegetation and the expected percentage of each species of the composition of the climax plant community on a typical clay loam range site are given in Tabled 11. The potential total annual production of vegetation in favorable, normal, and unfavorable years is about 2,000, 1,500, and 1,000 or less pounds of dry matter per acre, respectively.

In addition to knowing soil properties and the climax plant community, range management requires evaluating the present condition of the range vegetation in relation to its production potential. Range condition on a particular range site is determined by comparing the present plant community with the climax plant community for the site. The more closely the existing community resembles the climax community, the better the range condition (Figure 34). The objective in range management generally is to control grazing so that plants growing on a site are similar in type and percentage composition to the climax plant community for that site. Such management generally results in the maximum production of vegetation, conservation of water, and control of erosion. But sometimes a range condition somewhat below the climax meets grazing needs, provides desirable wildlife habitat, and protects soil and water resources.

The major management concern on most rangeland is to control grazing so that the types and percentages of plants that make up the climax plant community can become reestablished. Controlling brush and minimizing soil erosion by wind are also important management concerns. Aids to good range management include adequate fencing so that different tracts can be grazed on

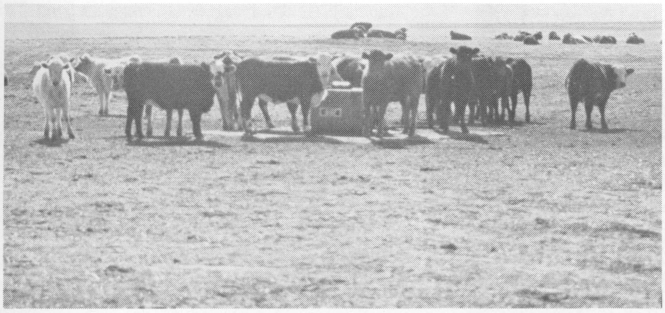

*Figure 31. Stocker cattle at a water source on Sherm soil.*

*Figure 32. Stubble from summer crops provides some forage during winter months for cattle grazing on adjacent wheat pastures.*

*Figure 33. A heavily grazed rangeland site.*

*Figure 34. Cattle on a well-managed rangeland site on Sherm soil. (USDA-Soil Conservation Service photo).*

a rotation basis and strategic positioning of water (Figure 35) and mineral supplement sources so that the livestock will visit different parts of the tracts during their daily quest for forage, water, and minerals (Merrill, 1983). If sound range management based on soil information and rangeland inventories is applied, the potential is good for increasing the productivity of rangelands.

## SUMMARY

With a land area of 1.3 million acres, Sherm soils are among the major arable soils in Texas. A small area of Sherm soils also occurs in Oklahoma. The area of Sherm soils is bounded by the breaks above the North Canadian River on the north, the caprock escarpment of the Canadian River on the south, the caprock escarpment at the High Plains-Rolling Plains boundary on the east, and a catena of loamy soils extending from Kerrick to near Channing on the west. Sherm soils occupy about 75 percent of the land within this area. The remaining area is composed of soils mainly associated with the playa lakes that are found throughout the area.

About 89 percent of the Sherm soil area is cropland, 9 percent is rangeland, and the remainder is in roads, towns, and other non-agricultural uses. Irrigation is used on about 70 percent of the cropland area. Major crops are wheat, grain sorghum, and corn.

To determine the variability of soil characteristics, Sherm soils were sampled at 11 widely separated locations. The profiles were described in the field at sampling time, and samples were analyzed in the laboratory for sand, silt, and clay content; organic matter content; pH; bulk density; $CaCO_3$ equivalent; and water retention. Plant-available water was calculated from horizon thickness, bulk density, and water retention values. Water infiltration was measured at the sampling sites.

The thickness of the profiles was highly variable, ranging from a depth of 44 inches to a calcic horizon at Site 5 in Sherman County, Texas, to 93 inches without reaching a calcic horizon at Site 8 in Hansford County, Texas. Depth to the calcic horizon, where present, ranged from about 44 to about 60 inches. In general, the profiles had less sand and more silt and clay in the eastern province than in the central and western provinces. Associated with the higher silt and clay contents were

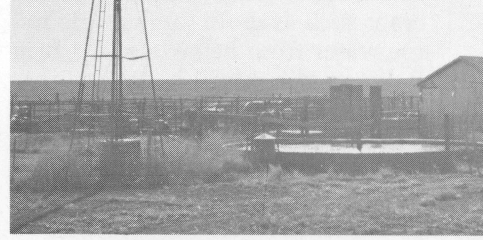

*Figure 35. Strategic positioning of wa sources plays an important part in effec utilitzation of range grasses.*

TABLE 11. TYPICAL VEGETATION ON SHERM SOILS (CLAY LOAM RANGE SITE)

| Plant name | | Percentage of annual production of dry matter |
|---|---|---|
| Common | Scientific | |
| Blue grama | *Bouteloua gracilis* | 40 |
| Buffalograss | *Buchloe dactyloides* | 25 |
| Sideoats grama | *Bouteloua curtipendula* | 5 |
| Western wheatgrass | *Agropyron smithii* | 5 |
| Vine-mesquite | *Panicum obtusum* | 5 |
| Silver bluestem | *Andropogon saccharoides* | 5 |
| Tobosa | *Hilaria mutica* | 5 |
| Other perennial grasses | — | 5 |
| Perennial forbs | — | 5 |

higher mean water retention values, which generally resulted in a greater capacity to store plant available water.

Total water infiltration and infiltration rates at 10 min were highly variable and seemed more closely related to bulk density of the Ap horizon at the time of making the infiltration measurements than to any other determined profile characteristic. Total infiltration at 20 hrs ranged from 1.41 inches at Site 6 in Moore County, Texas, to 15.66 inches at Site 3, also in Moore County. The low total infiltration in 20 hrs resulted from low infiltration rates from 1 to 20 hrs after applying water, and probably resulted from past management in the field. Other fields in the vicinity may not have such low infiltration.

Various measurements indicated that about 24 or fewer hours of water application would provide the profile with 5 inches of water at most sites; more time would be needed at others. The profile has capacity for greater storage at some sites, but from about 5 to 125 more hours would be needed to store each additional inch of water. Applying irrigation water for more than 24 hrs is not practical because tailwater runoff losses become excessive. Also, crops such as grain sorghum do not use water from below about 4 ft in Pullman soil, which is a soil similar in many aspects to the Sherm soil. Therefore, unless deep-rooting crops such as sunflower, wheat, or alfalfa are grown, complete filling of the profile with water may not be desirable. When crops such as sorghum fail to use water from deep in the profile, a rotation involving a deeper-rooted crop can result in more efficient use of water by extracting some of the deeply stored water, provided the soil throughout the profile contains adequate water for root growth. At some sites, the measurements suggest that deep percolation of water may be a problem. In such cases, management practices that minimize deep percolation should be adopted.

Because of declining supplies of water for irrigation, water conservation has received considerable attention in recent years. Practices that conserve water from rainfall, such as conservation-bench and level-bench terraces, contour furrows, blocked furrows, and the limited- and no-tillage systems, are applicable to Sherm soils. These practices conserve water by reducing runoff, increasing infiltration, or reducing evaporation. Crop yields have been increased where these practices were used on Pullman soils and should give similar results on Sherm soils. Practices for conserving irrigation water include improved water application techniques, tailwater recovery systems, and no-tillage farming.

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